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Usage Analysis of Milwaukee County's Paratransit System: the Case of Potawatomi Casino and Veteran Affairs Medical Center Destinations

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USAGE ANALYSIS OF MILWAUKEE COUNTY'S PARATRANSIT SYSTEM: THE CASE OF POTAWATOMI CASINO AND VETERAN AFFAIRS MEDICAL CENTER DESTINATIONS

by

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ABSTRACT

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by

Po-Hsueh Chiu

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Under the Supervision of Professor Wilkistar Otieno

In order to protect the rights of seniors and Persons with Disabilities (PWDs), the United States government, through Congress, enacted the Americans with Disabilities Act (ADA) in 1990. The Act ensures that there is equity for persons with disabilities in all aspects of public services including employment, education, transportation, accommodation, commercial facilities and businesses and communication (Federal Register, 2010). In this study, we focus on the problem of transportation of PWDs, specifically in Milwaukee County in Southeast Wisconsin. The study was initiated as a collaborative effort between UWM's Industrial and Manufacturing Engineering team, UWM's Director of the Rehabilitation Research Design & Disability (R2D2) Center, Milwaukee County Office of Persons with Disabilities team and the MCTS-Paratransit Department Team. MCTS wanted to explore effect that increased ADA bus ridership would have on the paratransit system performance such as bus utilization by PWDs, PWD average waiting time as well as the average time in system. Since the MCTS

network is large, the team determined to pilot the study on the most used routes by PWDs in Milwaukee County that serve the two most visited destinations, namely, the **Potawatomi Hotel & Casino** and **Milwaukee Veterans Affairs Medical Center**.

We formulated three study objectives to achieve this broad goal. First, we sought to understand the current status of ridership for R14 which serves the Casino, and R23 and RBlue both of which serve the V.A. Medical Center. We used both observational data to determine destination accessibility. In this study, destination accessibility is defined as the ease with which PWDs can access the location from the bus stop. Therefore, we made travel observations to both destinations in the winter, thereby considering the worst case scenario in the winter season. In addition, ridership by bus was compared to the ADA paratransit system, which is offered through MCTS's Transit Plus Program.

Observations results indicated that while the V.A. medical center was accessible, the Casino was not accessible to PWDs. Lack of accessibility was determined to be predominantly due to poor bus stop design as well as the distance from the bus stop to the Casino entrance. In addition, ridership results indicated that paratransit ridership outweigh ADA ridership on the fixed bus route service by a ratio of 3 to 1. Ridership to the V.A. on the fixed bus route system is twice the bus ridership to the Casino. Though the reasons to access these two destinations are distinctively different—medical care versus entertainment, we observed that the unfriendly environment in the Casino bus stop might the largest contributor to the low ridership on route R14. The study results also found that while fixed bus route ridership significantly changes by seasons, this effect was not significant for ridership on the ADA paratransit service.

The second objective sought to simulate the current fixed bus ADA usage. This was done to create a baseline on which potential changes to the system could be incorporated and their effects determined. In the third objective we make a potential alteration to the system, where a few potential riders who use the ADA paratransit through Transit Plus are switched to use the fixed bus route. In this study, PWDs who use the ADA paratransit are deemed potential for fixed bus route if they geographically reside less than 0.5 miles away from the route bus stop.

Therefore, two simulation models, I and II were developed and implemented. The first model simulated the current annual ridership of R14 to the casino. Due to study time constraints, only ridership to the Casino was simulated. The results of Model I indicated that the annual average ridership was about 7 per day. The 95% confidence interval of the passenger waiting time was [10.22, 13.09] minutes, which was evidently in the summer. Winter average waiting time confidence interval turned out to be [8.96, 12.96]. On the other hand, since all buses can only accommodate at most two PWDs on wheel chair or scooter, we were interested to know if this constraint increased the waiting time for PWDs using these mobility devices. The results showed that the 95% confidence interval of the average waiting time for PWDs using wheel chairs was at most (summer) [10.58, 13.22].

Simulation model II, an extension of model I incorporated potential PDW riders who currently use ADA paratransit into the fixed bus route in model I. The simulation process involved a combination of three software—Batch Geo, ArcGIS as well as ProModel. The results indicated very little effect of additional riders on the waiting time. For instance, the 95% confidence interval of the average waiting time for non-wheelchair users was [9.88, 14.15] minutes, while the interval waiting time for wheelchair riders was [9.44, 13.20]. In the other hand, the 95% confidence interval for the average time in system for all passengers (with or without a wheel chair) was estimated as 29.87 to 38.34 minutes. Finally, the bus utilization by PWDs in this study was measured as the percentage of the number of bus runs in the simulation carrying at least one PWD to the total bus runs. The average utilization was found to be 6.5%. This percentage is an indicator of that MCST has potential to increase fixed bus route ridership by persons with disabilities, especially if challenging issues such as low bus frequency, less geographical coverage of the bus network (to cover areas where most Casino ADA visitors reside), public transport awareness, bus driver training and most of all, increased accessibility of the Casino destination.

DEDICATION

To

My father Wen-Chieh Chiu, and my mother Pi-Lian Kuang.

Without your love and patience I would not have made it this far.

Dedicating all work to my Heavenly Father.

Glory in Your name.

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Chapter 1 Introduction

1.1 Background

In order to protect the rights of seniors and Persons With Disabilities (PWDs), the United States government through Congress enacted the Americans with Disabilities Act (ADA) in 1990. The purpose of the ADA is to ensure provision of equal opportunity and therefore prevent discrimination against people with disabilities in the public and private sectors, which include employment, education, transportation, accommodation (commercial facilities) and communication [1]. According to the ADA, qualified persons with disability include persons with the following conditions and impairments: deafness, blindness, an intellectual disability (formerly termed mental retardation), partially or completely missing limbs or mobility impairments requiring the use of a wheelchair, autism, cancer, cerebral palsy, diabetes, epilepsy, Human Immunodeficiency Virus (HIV) infection, multiple sclerosis, muscular dystrophy, major depressive disorder, bipolar disorder, post-traumatic stress disorder, obsessive compulsive disorder, and schizophrenia [2]. Approximately 56.7 million people living in the United States had some kind of disability in 2010 [3]. Given the percentage of aging baby boomers, the population of persons with disabilities is promising to increase gradually in the future. Consequently, the demand for paratransit will defiantly increase over time.

According to the Transit Cooperative Research Program – Report 163[4], which is sponsored by the Federal Transit Administration, the ADA does not require people with disabilities to use the publicly available fixed-route transportation system. Instead, mandates the provision of alternative transportation for users who due to their disability are unable to use the existing fixed route transit systems. However, there are increasing campaigns to improve the conditions within the fixed route systems to increase usage by PWDs. These improvements include increased awareness of the fixed route options, reduced distances between bus stops and stations, improve station accessibilities, improve harnesses for wheel chairs and scooters as well as improved personal relations among bus drivers. Many public transportation agencies across the nations have free or reduced fare ridership programs to encourage PWDs to consider the fixed route bus system for their daily commutes.

The ADA obligates every public transit organization operating a fixed route system to provide all disabled passengers with an alternative paratransit service that is comparable to the level of services provided to the general public. In addition, the service is required to provide a demand-driven response services referred to as door-to-door or curb-to-curb services without necessarily having fixed routes or schedules [5]. To use these paratransit services, customers must reserve the ride in advance (as specified by the service providers) and provide the time and location of departure and destination. The ADA paratransit system, also called demand response or dial-a-ride, offers the disabled customers a better service than the scheduled bus services. The window time is required in every pickup and drop-off to define punctuality of passengers and drivers [6].

Paratransit services can be provided by any ADA-compliant transit vehicle ranging from passenger automobiles, small mini-vans up to full-size heavy duty buses [7]. The small mini-vans have high maneuverability to drive through any kinds of the avenue or street. However, the mini-vans can only afford two wheelchair/scooter spots. They are also ramp-enabled instead of lift-enabled. Another often used class of paratransit vehicle is the cutaway bus. This bus has a wheelchair lift and it can typically sit up to 15 passengers include the driver. Depending on different agencies, the arrangement in the vehicle can be set to maximize the wheelchair capacity, as well as ensure adequate balance between wheelchairs/scooters and fixed-seats.

In each paratransit service vans, now equipping active surveillance cameras which the purpose can tracking the traveling status, while a question as to which description most accurately characterizes key details of the incident can be answered conclusively and resolve disputed service incidents.

According to the 2013 Public Transportation Fact Book[6], in 2011, close to 7,100 organizations provided public transportation in the United States of America. Out of these, approximately 6,600 not-for-profit organizations provided the dial-a-ride system, available for paratransit, thus making it the largest number of public transportation service providers in the nation. The transit service is operated by non-profit (73%), for-profit rural (17%), and for-profit urban (10%) operators and public transit agencies. Also, in 2011, the total operating expenditure for paratransit was $ 4753.5 million while the revenue from fares was $ 449.8 million. Among the total operating cost, $ 2383.5 million was spent for purchasing transportation equipment and $ 245.7 million was spent in services.

To mitigate the increasing cost of paratransit, the U.S. Government requires fixed-route transit systems to be the major service providers for PWDs. [4] In the publication, the board notes that though the overall increased usage of fixed-route service benefits both people with disabilities and the transit industry, there are challenges that PWDs face in using fixed-route transportation systems. These include:

1. Complete inability to use fixed-route services: This includes PWDs whose conditions cannot allow them to use the fixed –routes even if the accessibility is increased.
2. Incomplete accessibility: This occurs when some of the buses in the fleet are inaccessible, or some of the stops are not PWD-friendly.
3. Limited experience on traveling by bus or train: Some transit agencies are only providing paratransit service instead of fixed-route service; PWDs may feel difficult for changing their mind to use fixed-route service even they have ability to use.

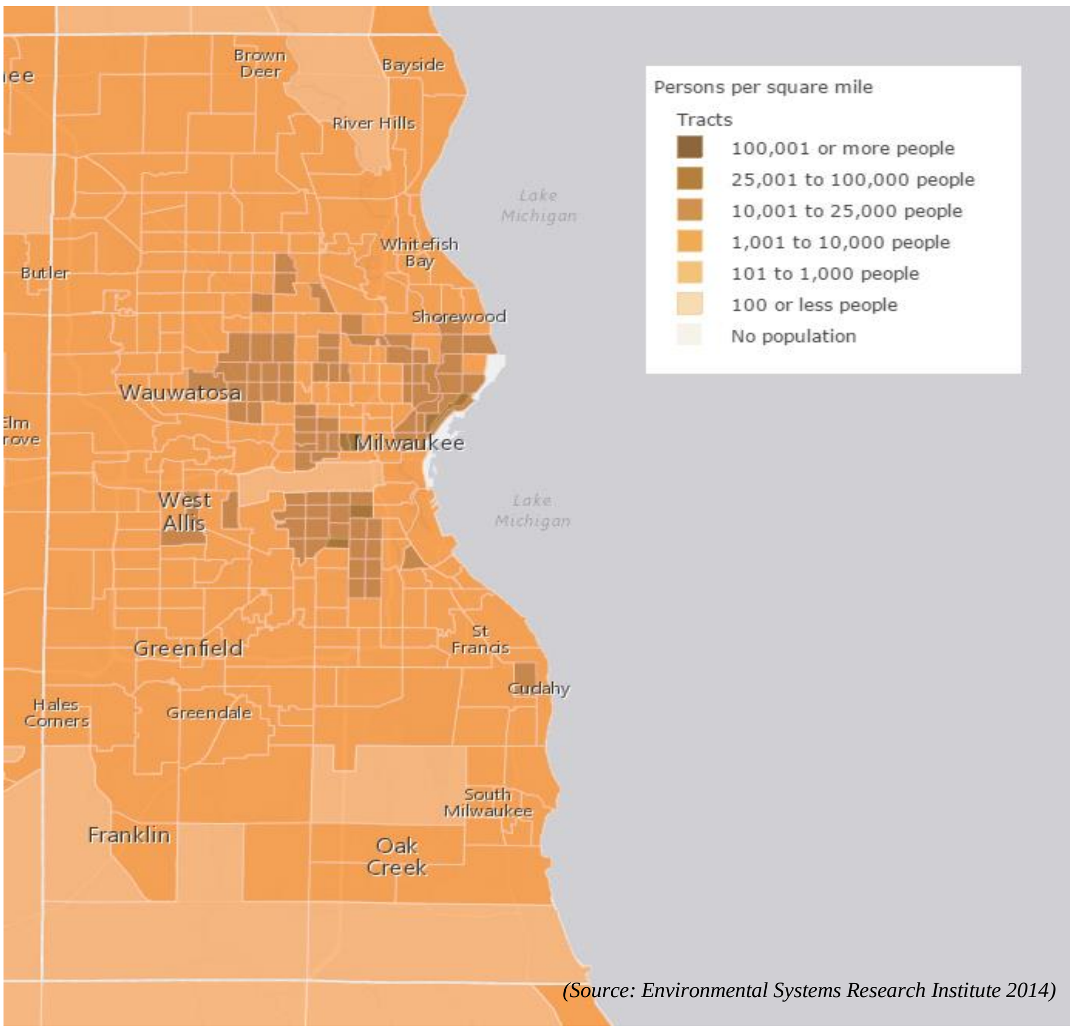
4. Complex processes for eligibility determination of ADA paratransit: To make the decisions for the individuals with which type of disabilities and different levels of ability can use fixed-route transit services is difficult. Each applicant is unique and it needs to be carefully decided with a series of auditing.
5. Insufficient positive experiences to PWDs for using the buses and trains: Past experience and outdated perceptions of using fixed-route transit service still influence some of PWDs. The inefficient or problematic boarding and securement are another issue for the "attention" and perceived "disruption."

To increase ridership, the TRB proposes several actions to improve ridership by PWDs. These include: (1) accessible bus stops and pedestrian infrastructure, (2) improved marketing, (3) efficient scheduling, (4) enhanced travel training (for clients and providers), (5) fare incentive programs, and (6) alternate transit service designs.

In this research, we study the current status of paratransit in the Milwaukee Metropolitan with the goal of simulating the performance of the fixed-route and demand-driven systems, both of which are provided by the Milwaukee County Transit System. Particularly, we are interested in the performance of the system to the two mostly visited sites by PWDs in Milwaukee namely, the Potawatomi Hotel & Casino and the Veteran Affairs Medical Center (V.A.).

1.2 Milwaukee Transit Current Status

Milwaukee County covers a geographical area of 242 square Miles in Southeastern Wisconsin. According to the U.S. Census Bureau[8], Milwaukee's population was s estimate to be 599,503 people in 2014. Figure 1 shows the population density distribution within the Milwaukee County. The number of people with disabilities is estimated to be 120,919, thus about 12.8% of the population as shown in Figure 2.



(Source: Environmental Systems Research Institute 2014)

Figure 1 Milwaukee County Population Density Distribution

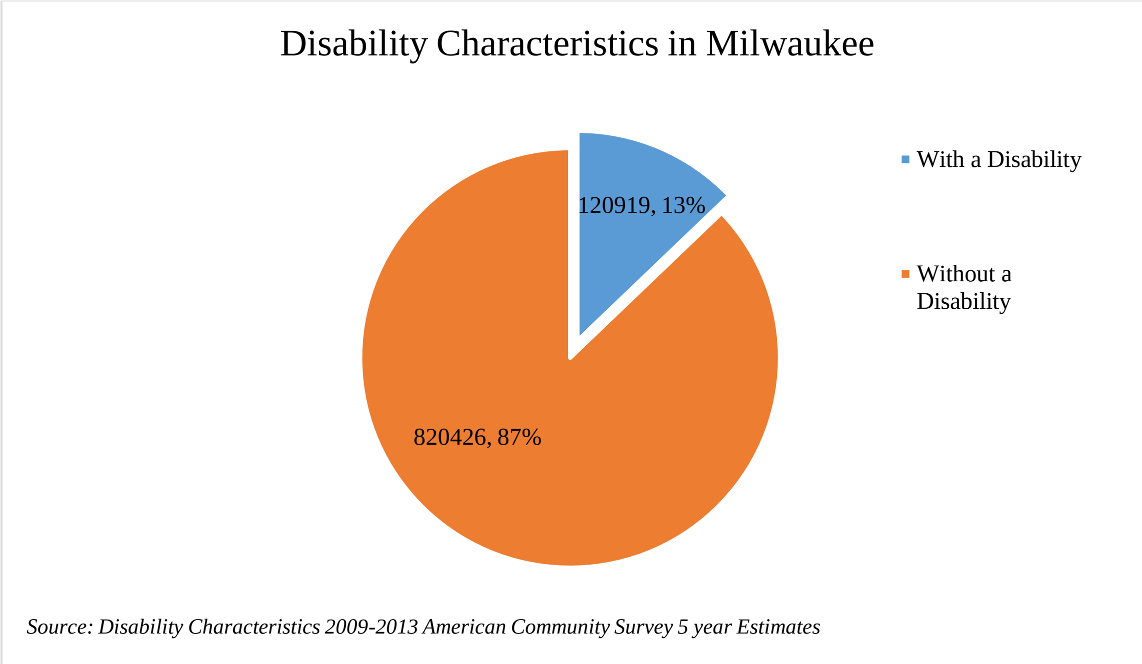
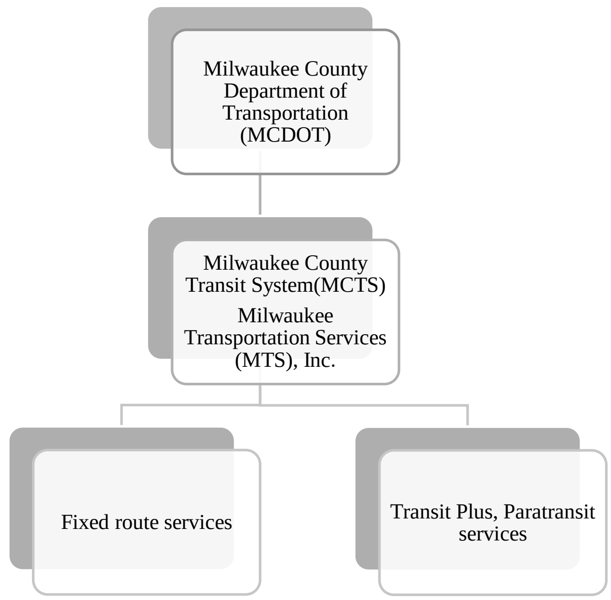


Figure 2 Disability Characteristics in Milwaukee

Milwaukee County Department of Transportation (MCDOT) provides public transportation services through the contacted transit agency namely, the Milwaukee County Transit System (MCTS). MCTS is the largest transit agency in Wisconsin, and it ranks among the top 50 transit agency with the most ridership in the United States. MCTS is currently operated by the Milwaukee Transport Services Inc. (MTS). Paratransit services on the other hand, are provided through several conduits, i.e. MCTS through the Transit Plus Program as well as the fixed bus routes, private service providers, as well as other non-profit corporation affiliated with MCDOT.

Figure 3 shows an abbreviated organizational chart depicting the relationship between Milwaukee County Department of Transportation (MCDOT), MCTS and MTS in providing paratransit services.



(Source: 2013 Milwaukee County Adopted Budget and Milwaukee County Transit System Website)

Figure 3 Organizational chart of Transportation

Transit Plus Program: Paratransit Services

The MCDOT administers and manages the contract between MTS and the county. Under the MTS, a program called "Transit Plus" provides accessible transportation services for PWDs with ADA qualification that are unable to use fixed-route bus. The Transit Plus program provided two forms of transportation—taxi cab services, for more ambulatory clients and van service for more physically challenged clients. Paratransit operations include the provision of demand driven dial-in transportation services as well as client-based regular services for clients who have a standing schedule agreed upon months in advance. The overall operating expenses for Transit plus was budgeted at $19.0 million (in 2013). Program revenue realized in 2013 was $ 17.6 million, resulting in a tax levy support of approximately $1.3 million.

Two private vendors provide Transit Plus van service, namely, Transit Express, which is the primary service provider for the northern portion of Milwaukee County, while First Transit is the primary service provider for the southern portion. The total paratransit scheduled and provided rides were 414,834 in 2012. Figure 4 shows that Transit Express provided approximately 60% of the paratransit van service rides in 2012, while First Transit provided approximately 40% of the rides. On time performance of these Transit Plus van service provider averaged at 95.7% since 2012. [9]

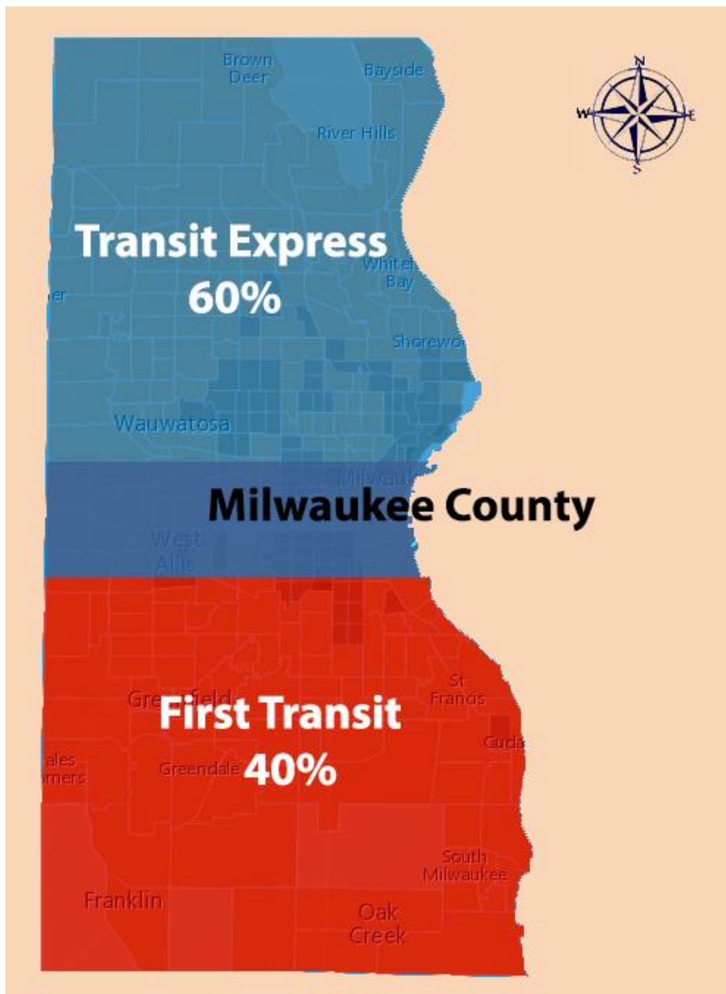


Figure 4 Van Providers Possession Percentage in Milwaukee Country

According to Federal guidelines, the official regulation of the allowable client waiting window time is up to 30 minutes. Transit express' average client waiting time is over 25-minute in only 5.0% of its rides, while First Transit exceeded this limit in 3.2% of its rides. The following is a summarized list of the primary factors that impact punctuality of van service providers especially in Milwaukee:

1. Extreme weather: During the four months of December, January, February and March, as a result of snow or poor road condition, the on-time performance for both of providers is negatively affected.
2. Regular service or demanded requests: Regular service refers to subscription rides include clients going to and from work or to regularly scheduled appointments. Conversely, medical appointment, social event, recreation activities or personal business imply client demanded requests, which usually have higher waiting times than regular service. [9]

Fixed-Route Bus Services

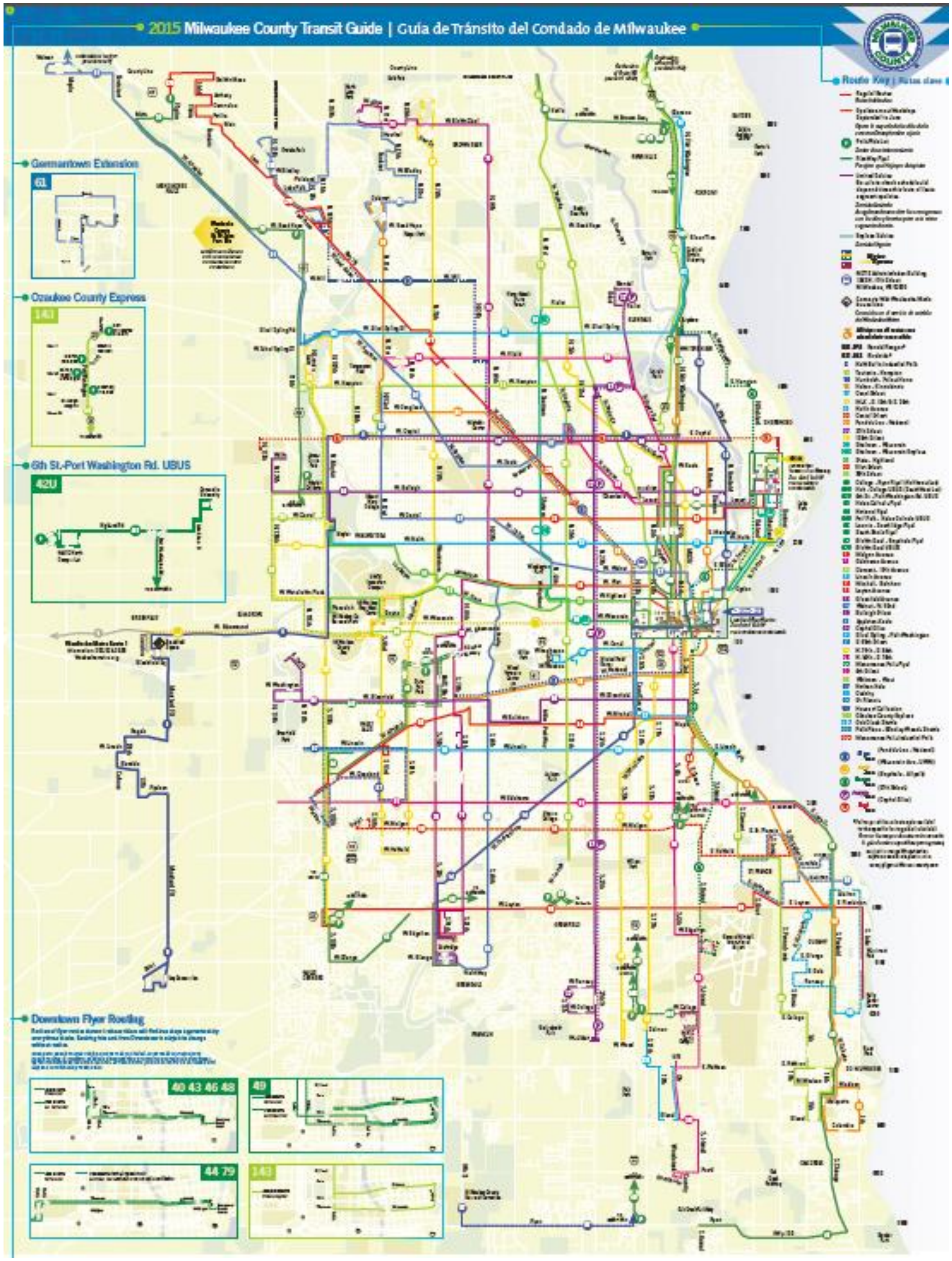
Throughout Milwaukee County, MCTS is the primary provider of the public fixed-route services. Table 1 shows the total service area of fixed-route services, which cover all of Milwaukee County. During 2013, the total bus operating hours was 1,328,034, while; the total passenger ridership was 43,008,924.

Table 1 2013 MCTS Fixed-route Bus Service Statistics

Service Area/Milwaukee County	242 Square Miles
Bus hours	1,328,034
Total passenger ridership	43,008,924
Bus stops	5,434
Routes	54
Number of buses in operation in AM Peak time	327
Number of buses in operation in PM Peak time	322
Average age of vehicle	5

(Source: Milwaukee County Transit System Website)

As it can be seen from the MCTS summary, there are a total of 5,434 bus stops for riders in Milwaukee County, 54 different bus routes for passengers for diverse purpose including work, recreational, shopping, medical and school. Figure 5 demonstrations the routes distribution and coverage in 2015. Furthermore, on average, 325 buses are used during AM and PM peak times. For purpose of accessibility, all MCTS buses have a kneeling mechanism that allows for a low-floor design i.e. the front two-thirds of the bus is at curb level. They are also equipped with ramps to facilitate boarding by wheelchair users. As for the interior of bus, special seats that can be folded up are incorporated to create securement areas for wheelchairs or strollers. In addition, hooks have been provided to stabilize the wheelchair in the bus while the bus is moving. Each bus can accommodate a maximum of 2 wheelchairs or scooters.



(Source: Milwaukee County Transit Guide 2015)

Figure 5 MCTS Bus Route Map

In order to enhance ridership as well as the convenience for the PWDs and seniors using public transportation, the MCTS established the free transit pass in March 2015. MCTS allows eligible seniors and people with disabilities who meet the ADA requirements to acquire unlimited free ride for fixed bus route services.

Taxicab Paratransit Service:

Taxi services provide another option for PWDs transport besides the paratransit and fixed-route services. Taxi services are not within the scope of ADA curb-to-curb service. However, PWDs can still request taxi service if a wheelchair passenger is able to transfer from the wheelchair to the back seat of a taxi with minimal or no assistance. Furthermore, Taxi drivers do not have responsibility to telephone riders upon arrival, and are not required to wait five 5 minutes for passengers to come to the taxi as it is with the paratransit van services. Such cases that require waiting are considered “No-Shows”. Table 2 gives a comparative summary of the different fares for each transit service.

Table 2 Services and Fares

	Fares	Remarks
Fixed-route service	$ 0 (with Go free pass) $ 1.15 (with ADA qualification without Go Pass) Original price for regular public: $2.25	
Paratransit Service	$ 3.5 each trip	
Taxicab	Initial $4.00 rider fare (If the meter exceeds $14.60, the rider is responsible for the initial $4.00 fare, plus any amount in excess of $14.60.)	Taxicab trips charges are determined using time and mileage-based meters

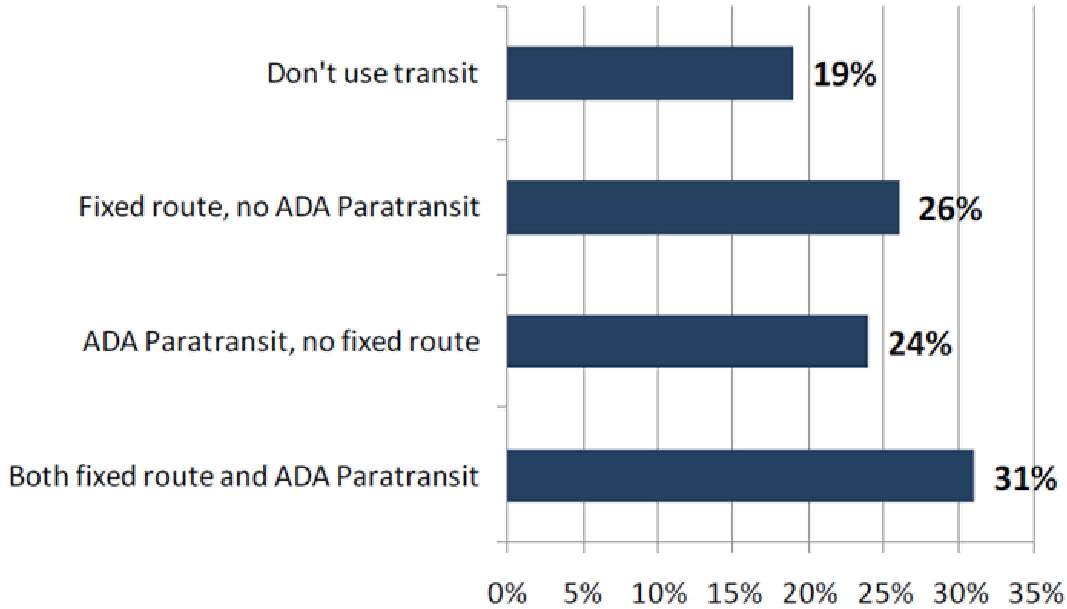
(Source: Milwaukee County Transit System Website)

1.3 Problem Statement

According to the ADA regulation, the fixed-route and paratransit services should provide sufficient, convenient, effective and quality mobility to PWDs similar to those offered to regular users. PWDs transportation should easily accessible and schedules should also be provided for the PWDs to conveniently schedule both the time and mode of travel. Fixed-route and paratransit service have different characteristics as was mentioned in Section 1.1 section as such riders have to consider (1) accessibility, (2) mobility, (3) travel time, (4) cost-effectively, further (5) reserved requirement in their travel decision making process.

In reality, since the paratransit option offers door to door services, it displays better performance than fixed-route system especially when accessibility and mobility aspects are considered. Base on that, more ADA qualified passengers prefer paratransit service than fixed-route. In addition, weather issues, time of travel, individual challenges of PWDs such as the visually impaired and those on wheel chairs adversely affect the use of fixed bus route services by PWDs.

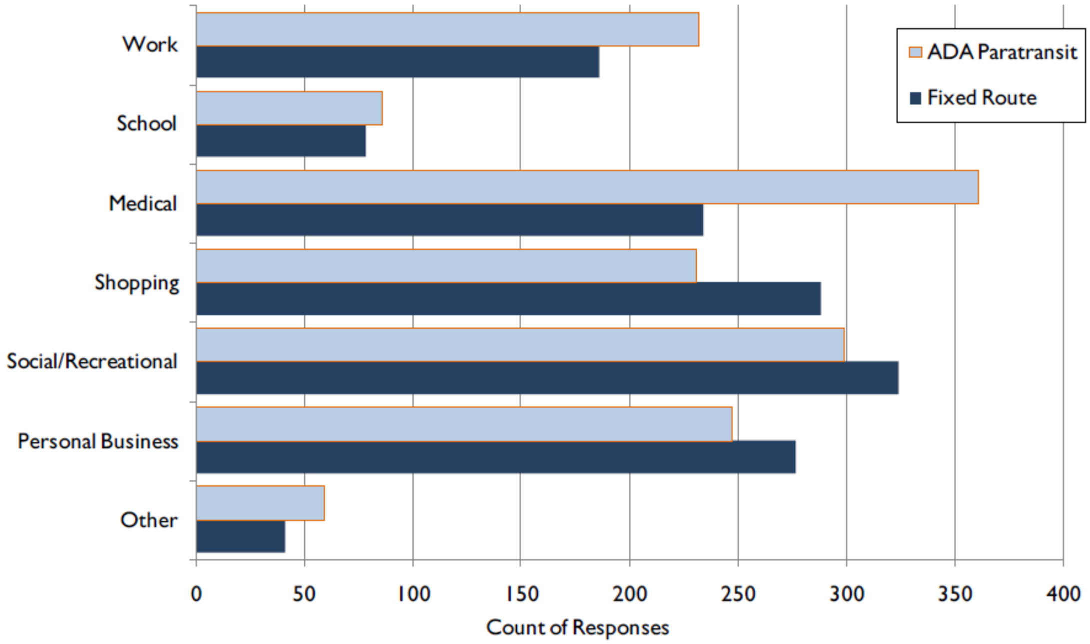
This report [4] contained findings from a study that surveyed 1,927 people, of whom 67% were PWDs while 33% responded on behalf of a family member or close associate who is a PWD. Approximately one third were from larger U.S. cities while the rest were from smaller cities, suburban and rural areas. 38% were people with mobility disabilities; 23% blind or visually impaired; and the remainder had intellectual or cognitive disabilities. Survey respondents also indicated a varied use of transit services. 31% indicated use of both fixed-route transit service and ADA paratransit, 24% indicated use of ADA paratransit service (without an possible fixed route nearby. 26% indicated that they use the fixed-route transit service but not ADA paratransit service at all, and 19% indicated they don’t use either service as shown in Figure 6.



(Source: Transit Cooperative Research Program – Report 163)

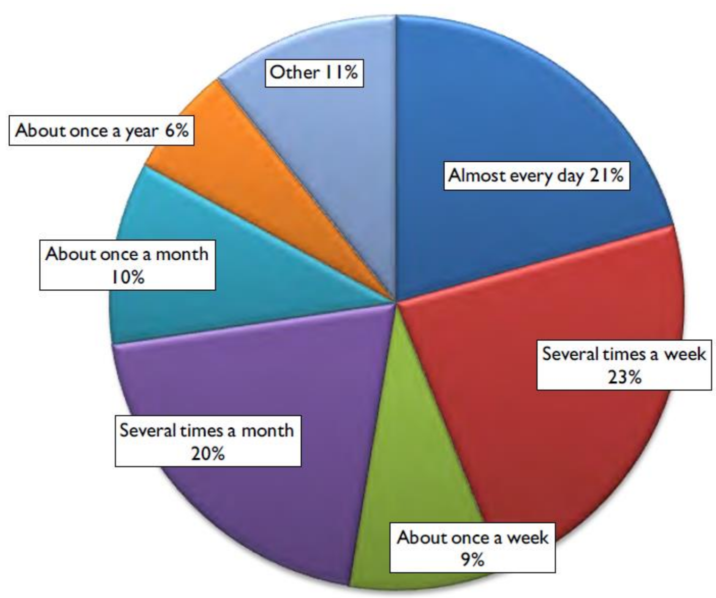
Figure 6 Survey Responses by Current Use of Public Transit Services

Cumulatively, the respondents who use both ADA paratransit and fixed bus route services indicated the following reasons for seeking transportation as shown in Figure 7. Similar trends of usage were also reported for respondents who use only one mode of transportation. Figures 8 and 9 indicate the frequency of use by the respondents who use the fixed bus route and ADA paratransit services respectively.



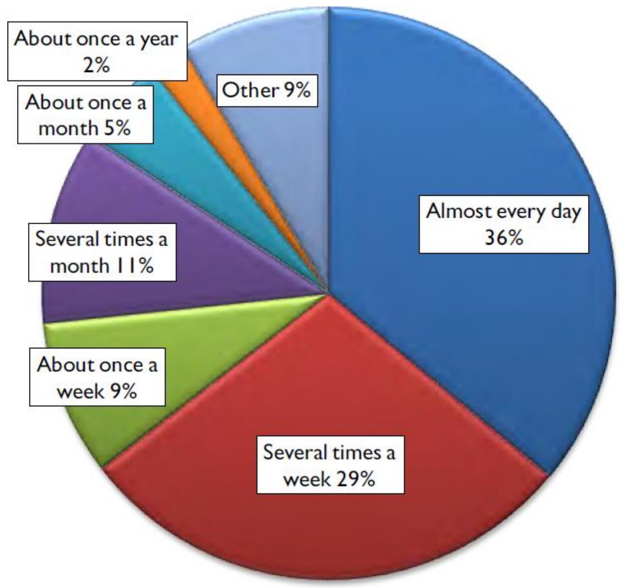
(Source: Transit Cooperative Research Program – Report 163)

Figure 7 Types of Trips by Modes for Respondents Who Use Both Fixed-Route and ADA Paratransit Services



(Source: Transit Cooperative Research Program – Report 163)

Figure 8 Frequency of Use by Respondents Who Use Fixed-Route

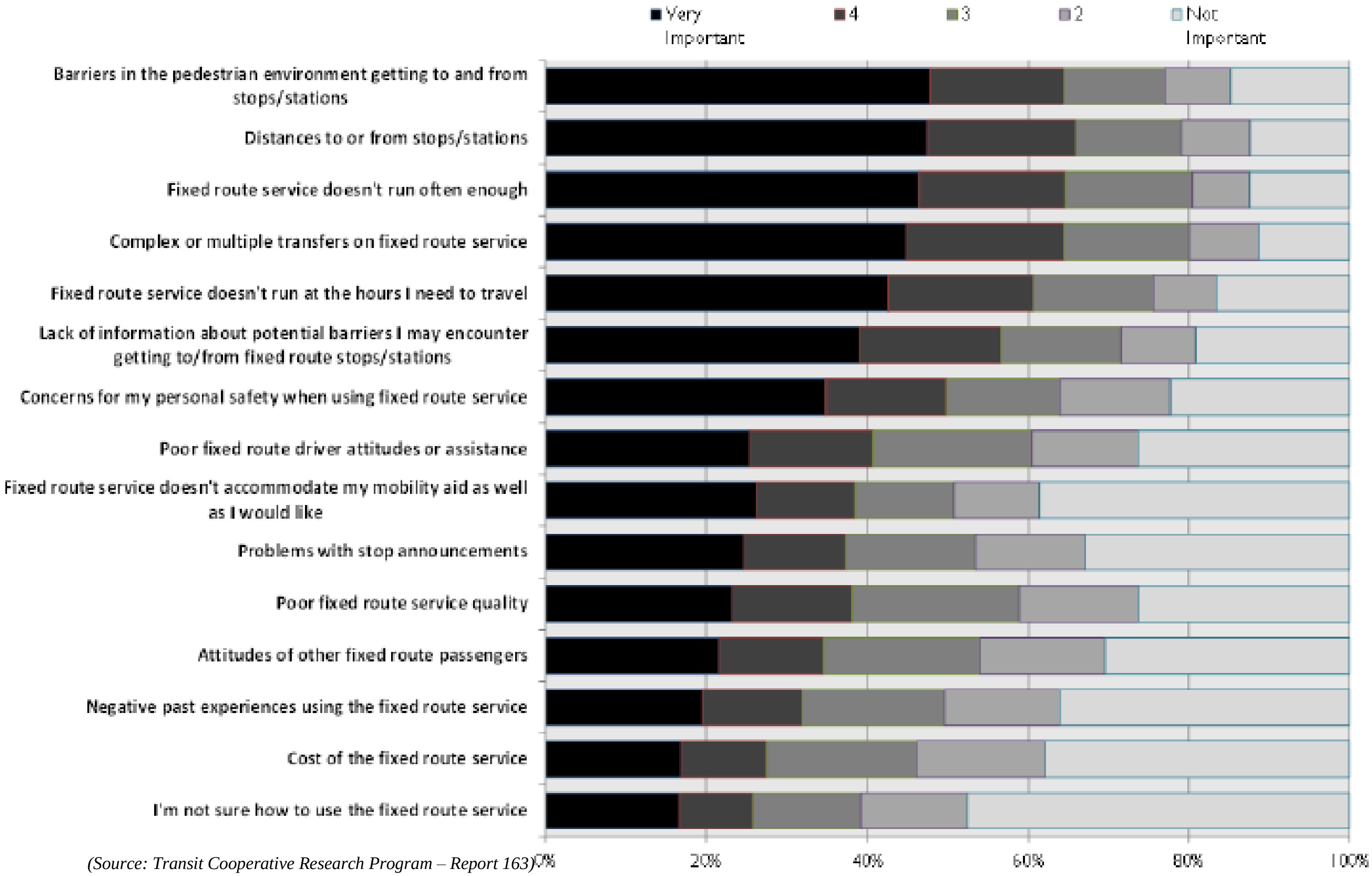


(Source: Transit Cooperative Research Program – Report 163)

Figure 9 Frequency of Use by Respondents Who Use ADA Paratransit Services

Of the respondents who use the ADA paratransit system only, when asked if they could reconsider using the fixed bus route system, 48% indicated no, 28% indicated yes, while 24% indicated not sure. On the other hand, of the respondents who use the fixed bus route service, when asked if they would like to use the fixed bus route more than they do, 53% indicated yes, 26 % indicated not sure while 20% indicated no. These statistics emphatically indicated that a significant percentage of PWDs are interested in the use of fixed bus route services. Thus, enhancements to the current fixed bus route systems and increased incentives would increase bus usage and hopefully reduce ADA paratransit usage which is usually more costly.

One focus of the above mentioned study was to determine factors that determine the choice transportation mode and factors that particularly deter fixed bus route service usage by PWDs. The results are summarized in Figure 10.



(Source: Transit Cooperative Research Program – Report 163)

Figure 10 Frequency of Use by Respondents Who Use ADA Paratransit Services

The most important factors that affect the fixed bus route usage include:

- Availability and level of service
- Distance to and from stops/stations
- Lack of information about the potential barriers in the pedestrian environment (such as the need to cross a street at the destination point)
- Complex and multiple transfers
- Barriers in the pedestrian environment to and from the stations

The following factors were deemed to be of moderate importance

- Concerns about accommodation of mobility device such as wheelchairs and scooters
- Poor transit driver (social stigma)
- Inaudible stoppage announcements and other important announcements
- Poor quality of transit service

The following factors were deemed less important

- Cost of fixed-bus services
- Ignorance in using the bus
- Negative past experience
- Attitude of other passengers

Lower fixed bus ridership which would inadvertently increase ADA paratransit ridership result in increased expenses incurred by MSDOT and MCTS. In Milwaukee County, as mentioned before, ADA paratransit services are offered through the Transit Plus Program (TPP). The TPP has subcontracted two companies to offer these services, i.e. north region serving Transit Express and First Transit which serves the Southern regions. According to the 2013 service statistic of MCTS [10], on average, the expense per client for paratransit services was roughly 9 times greater than that of fixed route ADA client service ($28.859 to $3.17), resulting in an aggregate annual ADA paratransit system cost total of $14,346,440 higher than PWD fixed bus route transit as shown in Table 3.

Table 3 Comparison of Transit Plus and Fixed Route in Expense Per Client

	Operating Expenses	Ridership	Expense for each client
Transit Plus	$15,710,000	544,357	$28.86
Fixed Route (ADA riderships only)	$1,363,560	430,090	$3.17

(Source: 2013 MCTS service statistic)

This study resulted from several working meetings between UWM-IME team, UWM's Director, Rehabilitation Research Design & Disability (R2D2) Center, Milwaukee County Office of Persons with Disabilities team and the MCTS-Paratransit Department Team. It was determined that the most used routes by PWDs in Milwaukee County serve the following two destinations; (1) **Potawatomi Hotel & Casino** (Casino), and (2) **Milwaukee Veterans Affairs Medical Center** (V.A.). In addition, the usage for fixed bus route services to these destinations is much lower than paratransit service usage.

1.4 Research Goal and Objectives

The overall goal of this research is to present a comparative system usage and cost analysis between the fixed bus route services and ADA paratransit services to the two destinations in the study. As previously mentioned in Section 1.3, increasing the usability of fixed bus route is poised to lower both clients and system operating costs. To reach this goal, we will adopt the following objectives.

Objective 1: Understand the current usage of fixed bus route and ADA paratransit services to serve as a baseline for the current and future studies. In addition, we seek to also analyze the accessibility of these two destinations by PWDs who use the fixed bus, which will strengthen the discussion of the usage results in chapter 5 of this study.

Tasks:

- Obtain data from MCTS
- Preliminary data pre-processing and Analysis
- Data summary and presentation

Objective 2: Simulate the current R14 fixed route service for PWDs to the Casino destination in order determine the current performance metrics including bus utilization, client waiting time, client time in the system, and total system cost (both client and MCTS).

Tasks:

- Establish a fixed route simulation model to analyze the current performance
- Compare the performance against the ADA mandated customer satisfactory levels

Objective 3: Simulate the fixed route service for PWDs to the two destinations when additional potential PWD riders are added and determine the performance metrics such as bus utilization, client waiting time, client time in the system, and total system cost (both client and MCTS).

Tasks:

- Obtain the Transit Plus Program data of ADA paratransit van usage to the two destination
- Pre-process the data to determine the geo-spatial location of the ADA paratransit users with respect to the current fixed bus routes
- Incorporate potential riders to the fixed bus route simulation model
- Obtain the performance metrics

1.5 Study Contributions

In this study, we provide the first detailed analysis of paratransit ridership to the Potawatomi Hotel and Casino as well as the V.A. Medical Center. Secondly, we development of a dynamic simulation model that incorporates an interface of Batch Geo and ArcGIS (geo-spatial software) and ProModel (simulation software) to analyze annual paratransit ridership on the ADA paratransit system as well as the fixed route bus system.

1.6 Thesis Organization

This thesis has six chapters in total. Chapter 1 introduces the background of this research, defines the major problems to be solved and presents the goal, objectives and tasks to be completed. Chapter 2 is a compilation of the literature review of prior work with regard to analysis and simulation of paratransit services. Chapter 3 presents the actual data obtained from Milwaukee County Office of Persons with Disability and MCTS-Transit Plus Program. Chapter 4 details the simulation model whose results are presented in Chapter 5. Chapter 6 included concluding remarks as well as potential areas for future studies. Figure 11 presents the procedure of this study.

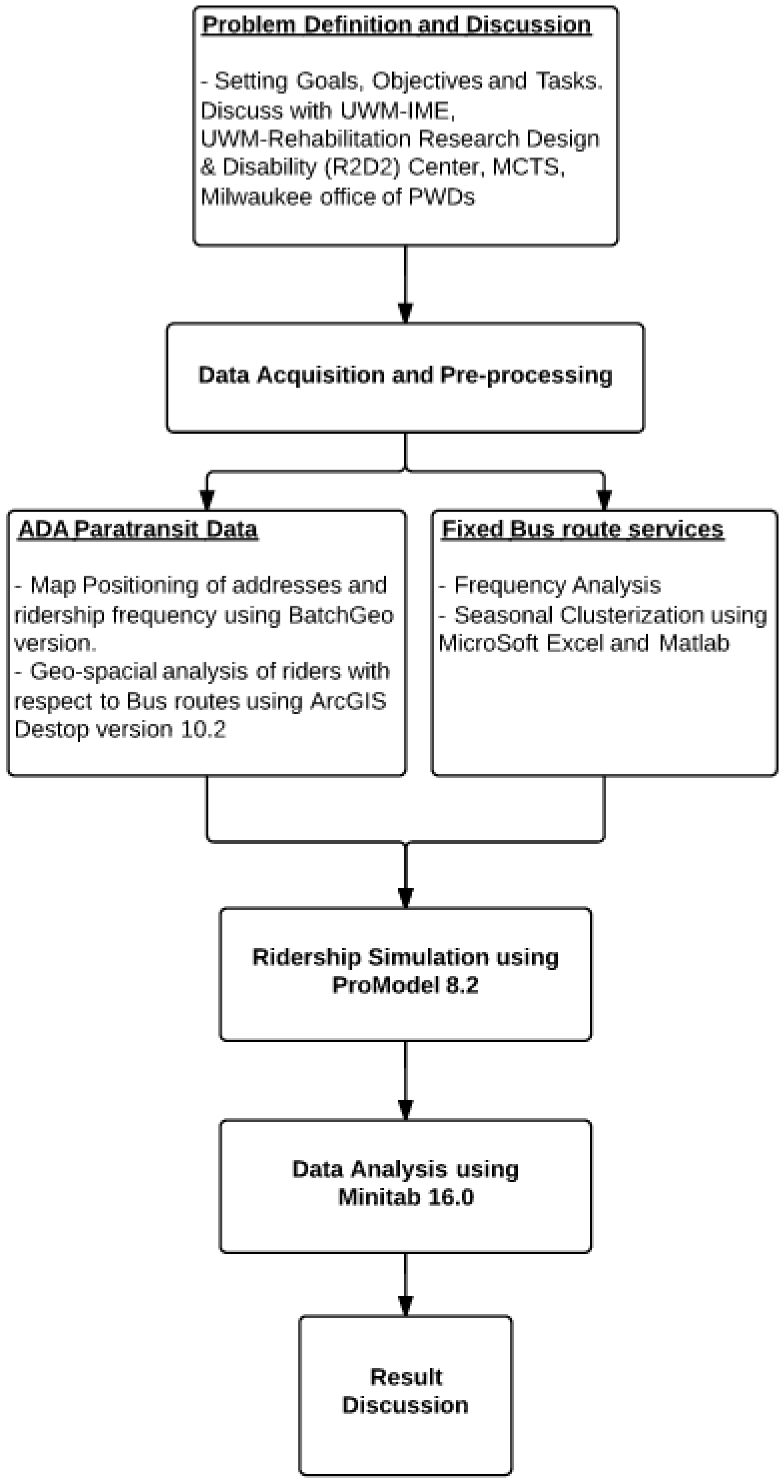


Figure 11 Research Procedure

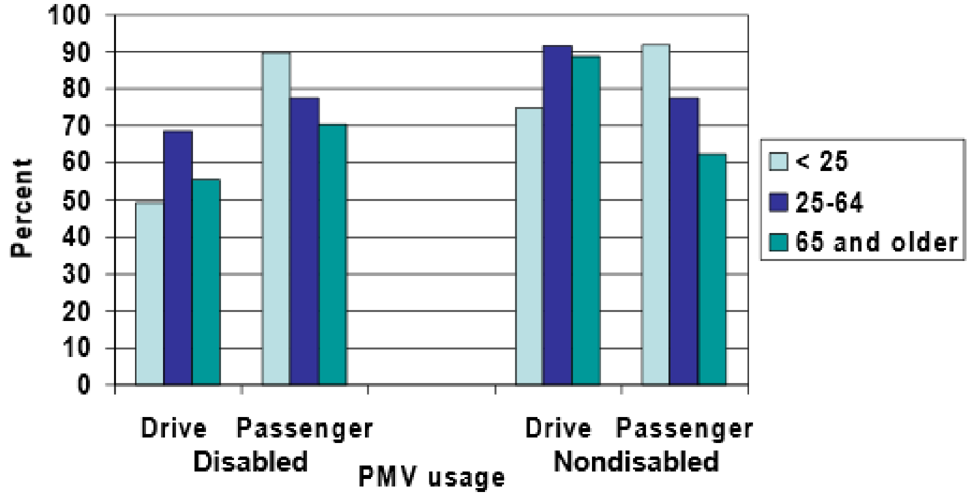
Chapter 2 Literature Review

2.1 Public Transit Patterns for Persons with Disabilities

Today, more than 40 million people in the U.S.A. have some kind of disability, and the number is likely to grow over time[11]. The future of the life of Persons with Disabilities (PWDs) is highly dependent on how the country will continue to enforce policies and manage the complex array of services and products offered to PWDs. These include fiscal, medical, transportation, and assistive technologies. This research considers the usage and performance of transportation modes accorded to PWDs, specifically fixed route and ADA paratransit services.

Public transit is quite vital to PWDs. For the past 20 years, in 2014 the National Organization on Disability (NOD) carried out surveys aimed at PWDs. In the survey about one third of PWDs maintained that there was inadequate or inconvenient transportation system available for them to use. More than half believed that these problems critically affected their day to day activities.

In 2002, the Bureau of Transportation Statistics (BTS) conducted a research on travel patterns considering used age groups and physical conditions. In total, 5019 reports respondents were involved in the study, of which 40% were self-identified PWDs. The survey categorized respondents into three age groups namely, > 25 years, 25 to 64 years and > 65 years. When asked about the modes of transportation that they used, private vehicles had the highest proportion of respondents. The Figure 12 indicates usage of private vehicles by both disabled and non-disabled users for each age set. According to Figure 12, there is about 10% difference in the usage of personal vehicles between PWDs and non-PWDs especially those whose age is 25 years and higher.



(Source: U.S. Department of Transportation, Bureau of Transportation Statistics, 2002 National transportation Availability and Use Survey)

Figure 12 Usage of Private Vehicles by both disabled and non-disabled

Irrespective of the age group, when the respondents were asked about factors that affected their ability to get the needed transportation, 34% indicated no or limited transportation, 26% indicated not having a car, 17% indicated that disability made it hard for them to use the available mode of transport and 11% indicated not having anyone to depend on for movement. Though this data was collected a decade ago, usage of public transport is still far much less than the usage of ADA paratransit services. Table 4 summarizes the 2002 study by the Bureau of Transportation Statistics (BTS). [11]

Table 4 Transportation Mode Used by Drivers and Nondrivers with Disabilities

	Percentage of People (%)	
Mode	Current Drivers	Non-drivers
Personal vehicle (driver)	96.9	3.1
Personal vehicle (passenger)	71.2	86.0
Carpool, vanpool	6.5	16.3
Public transit or city bus	5.0	26.0
Curb-to-curb ADA paratransit	2.0	12.6
Other specialized paratransit services	1.9	6.8
Private or chartered bus	3.2	5.8
School bus	2.6	3.4
Subway/light rail/commuter rail	4.0	10.6
Taxicab	5.8	21.9
Electric wheelchair, scooter, golf cart	5.3	6.9
Bike or pedal cycle	14.2	14.2
Walk, manual wheelchair, or scooter on sidewalks, crosswalks, intersections	48.2	40.2
Other	5.1	6.8

(Source: The Future of Disability in America)

2.2 Challenges of Public Transportation

Most public transportation agencies face the challenge of getting sufficient and stable funding not only for the operation and maintenance of their systems, but also management and system capacity expansion. They also have a perpetual challenge to keep their overall costs down. [12] To this end, most agencies have used a combined action approach including equipment upgrade, maintenance improvement, sufficient and suitable driver training, and more rigorous management inspection and response. However, for the past decade, passengers with disabilities have pointed out the same existing systemic problems that hinder their transportation (NCD, 2005). In addition, there are quit plenty of outdated buses-with improper lift and securement systems that have fallen into disrepair. [11]

The American Disability Act requires every bus to have two standardized wheelchair and scooter securement areas. It also requires training for all bus drivers on how to secure these transportation aids. Despite the fact that all bus transportation agencies have adhered to these mandates, the conventional fixing systems have severe operational and maintenance problems.

Researchers in the area of ergonomics have studied wheelchair securement jobs and the potential driver injuries that may be a reason why drivers are unable to successfully secure PWDs with wheelchairs or scooters[13]. However, it suffices to say that more transportation agencies are investing in improved securement equipment, driver training and in-bus surveillance. Such improvement projects have resulted in increased usage of bus systems by persons on wheelchairs.

The Milwaukee County Transportation System has reported a two-fold increase in Transit Plus Program(TPP) cost since 2000 compared to fixed bus routes costs. Particularly, TPP cost offered through the Transit Plus Program has increased by 80% since 2000, compared to 39% for the fixed route bus transportation services [14]. In future, such increases in paratransit costs could potentially draw local funding away from the fixed-route bus system. This would increase the potential for service cuts and fare increases for the bus system, particularly in the absence of dedicated local funding. The county therefore is keen to work towards increasing the usage of the fixed bus route system by PWDs.

Based on Milwaukee County Transit Service Development Plan, it is noteworthy that the use of the bus system by PWDs has increased, especially with the introduction of the Free Ride Program in 2014.

2.3 Remedies of Public Transportation Challenges

2.3.1 Improved Accessibility

As widely acknowledged, accessibility foe PWDs is equally significant whether it is to a small room within a building or a large building one within the metropolitan area. This is because PWDs need respects and sufficient assistance to live a decent life as the people without disability. This not only improves their quality of life by providing them with equal opportunities for travel to workplaces, public spaces and government agency buildings. Enabling PWDs improve their mobility is also a way to promote the local business and the overall economy of the society. [15]

[16] Address the aspect of accessibility measurements for people on landscapes, surfaces, barriers and modes of transportation. According to the ADA, “At least one accessible route within the boundary of the site shall be provided from public transportation stops, accessible parking, and accessible passenger loading zones, and public streets or sidewalks to the accessible building entrance they serve. The accessible route shall, to the maximum extent feasible, coincide with the route for the general public.” Their proposed access measure which aids in making a decision for an ADA to choose between competing venues include factors such as the spatial location of potential destinations, the ease of reaching them, and the magnitude, quality, character and importance of the activities for which the PWDs need to carry out in each destination. In this model, the greater the number of potential destinations, the higher the accessibility measure of a given activity.

An example of a case study that uses the accessibility measurement model is the study by Su et al. 2009. Their study investigated the factors that affect transportation preference for before and after shopping, by senior citizens and PWDs in London. The authors’ contribution is that the analysis of spatial variables fully manifests positive correlation or associability between accessibility measures and public transport use. In addition, for seniors particularly, factors such as bus stop density were most important in determining accessibility than quality of service and service frequency. They also conclude that improving and increasing public transit offerings will increase accessibility. [17]

In Milwaukee County, accessibility is being improved though the implementation of the Free Ride Program as well as physical improvement to bus stops such as constructing more curb-cuts, concrete pads, shelters, or benches. [14] Though this research is not concerned with accessibility measure, the choice of the two destinations in the study arose from the fact that they are the only destinations of their kind in Milwaukee County, i.e. V.A. Medical Center and the Potawatomi Hotels and Casino. The former has a well-designed bus stop, while the latter requires immediate attention, potentially through a joint venture between the MCTS and the Forest County Potawatomi Community who own and operate the Casino.

2.3.2 Personnel Training

Circumstances and the environment that surround the use of public transportation by PWDs are ever-increasingly friendly. This is made possible by adequate rules and regulations regarding driver training and execution of PWD assistance. Nevertheless, some PWDs still feel that driver impudent attitude and reluctance to offer assistance hinder their (PWDs') comfort in using public transportation modes. It is for this reason that continuous personnel training are pursued as a long-term solution to ensure a system public transportation environment for PWDs. [18]

2.4 Performance Metrics of Paratransit Systems

For the performance metrics of paratransit service, we have the information from the office for persons with disabilities in Milwaukee County. As they mention, almost 85% of scheduled client trips was provided by the van providers, and averagely one trip need to take about 38 minutes for the ride. To look at the on-time trips, 96.45% trips arrived within the constraint of time window, as well as the average distance for each trip is 6.86 mile. However, on the clients complain suggestions, most of the issue was happened in the winter season (November till February), because of the seasonal problem, for the door to door service, the client tends to stay at their house for waiting the paratransit van. And this condition will easily make the driver misunderstanding this client is not showing, and under the time schedule limitation and window time constraint, the driver will leave and going to take the next client. On the other hand, because the clients don't have any information assistive system (e.g. Transit schedule application the mobile phone, schedule table from the van provider) for them to check the status of the paratransit van (e.g. the location of their van and the estimate arrival time), they are hard to identify when will the van come to pick them up, moreover, some appointment location is hard to stop by in the winter time (e.g. ice cover on the ground, snowy day, lower temperature), so, it's hard for them to decide when is the best time to wait at the certain position and try not to stay outside too long. Some cases will miss the van because they cannot properly realize when the paratransit van will come.

2.5 Performance Metrics of Fixed Bus Route Systems

Fixed route bus service systems are mandated to provide adequate and accessible special seat assignment for PWDs. In addition, assistive device such ramps and kneeling bus devices must be incorporated. There must be at least two wheel chair or scooter securement areas in each bus. Milwaukee County Transportation Service estimates that there are about 9000 PWDs who qualify as potential users of the Milwaukee fixed bus route system per month, especially in the summer season. Moreover, some bus routes may have as much as 500 potential PWD users per month. However, in the winter time (November to February) as expected, the PWD bus users drop to as much as half of summer usage. The major reason being harsh cold weather conditions that would hinder PWDs from reaching the bus stops and wait for the bus, and impassable pavements on snowy or icy days.

Besides the weather, some bus shelters are offer dismal protection from the rain, sunshine and wind or are altogether not available. Some of shelters have no ramp for PWDs walk/ride on to access the bus stops. Finally, PWDs using the fixed route service have to consider not only the number of bus transfers need but also the time lapse between transfers. Because the PWDs will on average use double the time to board and alight from the busses, they could easily miss the transfer bus, hence be forced to wait longer than people without disabilities. Furthermore, whenever PWDs may need to use the fixed route service during peak times, crowded buses and wheelchair limitations may also hinder their ability and willingness to take the bus, thus increase their waiting times.

2.6 Evaluating Transportation System Performance using Simulation Approach

In Table 5, we display a quick preview of prior research papers that a simulation approach to evaluate paratransit service systems' performance. We indicate the main authors' names, title and year of study, the objective of the study and a brief comment on their results. Most of these research studies we done to evaluate performance of paratransit systems in the United Stated and Canada. Broadly, the emphasis in these studies include evaluation of projects incorporating assistive technologies such as cell phone and computer applications of vehicle positioning with respect to the clients position, time window size analysis, zoning strategies analysis and dial a ride service relative ride time analysis. We conjecture that, most of such analyses are related to ADA paratransit service systems as opposed to fixed bus route systems. Our study bridges this gap by adopting a simulation approach to evaluate usage of both the fixed bus route services and ADA paratransit services.

Table 5 Literature on Simulation Approach to Evaluating Transportations Systems

Title	Author	Software	Year	Research Area	Objective	Main Result
A simulation model for evaluating advance dial-a-ride paratransit system[19]	Fu	C++	2002	Edmonton, Canada	To facilitate the evaluation of the potential effects of phone-based assistive technologies on a paratransit system	The average increase in productivity (number of trips made) was between 2% and 4%
Simulation and performance of DRTS in a realistic environment [20]	Deflorio et al.	ARENA	2002	Canavese, Italy	To evaluating the efficiency of a Dial-a-Ride service with different Relative Ride Time.	Only 41% of the total passengers are picked up under "less prudent" user behavior.
Is dial-a-ride bus reasonable in large scale towns? evaluation of	Shinoda et al.	N/A		Virtual Town with grid pattern mimicking	To compare the performance of dial-a-ride system vs. a fixed-route system in urban	The usability of the dial-a-ride system with a fixed fleet of vehicles drops very quickly when the number of

usability of dial-a-ride systems by simulation[21]				Kyoto and New York	areas varying various parameters.	paratransit demand increases. Increasing the number of buses proportional to the demand, the usability of the dial-a-ride system is improved more significantly than that of the fixed-route system. When frequency of demands is sufficient, the dial-a-ride system is a reasonable solution from both usability and profitability perspectives.
An insertion heuristic for scheduling Mobility Allowance Shuttle Transit (MAST) services[22]	Quadrifoglio et al.	N/A	2007	Virtual location	To perform sensitivity analyses of the MAST system over the locations with varying shape configurations.	Slimmer service configurations perform better in general and are more suitable for public transportation purposes.
A simulation study of demand responsive transit system design[23]	Quadrifoglio et al.	N/A	2008	Los Angeles County	To analyze the effect of varying the time-window size (from 10 to 45 min) To compare the current decentralized approach with a centralized strategy where any vehicle can pick-up any customer regardless of the service region. To investigate the effect of centralizing only part of the service area, merging two regions together.	The operating factors and performance measures have a linear relationship. For each minute increase in time-window size, the system saves approximately 2 vehicles and 260 miles driven. No-zoning strategy can satisfy the same demand by employing 60 less vehicles and driving 10,000 less total miles with respect to the current zoning strategy.
Evaluating Centralized versus Decentralized Zoning Strategies for Metropolitan ADA Paratransit Services[24]	Shen et al.	N/A	2012	Houston City	To investigate the productivity and quality of service of certain zoning strategies for ADA paratransit systems, through an evaluation of both centralized and decentralized strategies.	The centralized strategy helps to increase the passenger trips per vehicle revenue hour. The decentralized zoning strategies decrease the average deviation time for customers.

2.7 Analyzing Fixed Route Transit and Demand Responsive Transit

Analytical modeling and/or simulations have been used to manage flexible transit service, which means combining two or more transportation modes for passengers to enhance accessibility. Following our investigation, literature mainly assist planners to solve service-mix decisions, such as the determination of the adjustments to me made to the fixed bus systems relative demand responsive transit that would optimize system performance . However, these research papers do not particularly address the paratransit system. Table 6 gives a summary of these research papers.

Table 6 Literature on Analyzing Fixed Route Transit and Demand Responsive Transit

Title	Software	Year	Objective	Main Result
Feeder transit services: Choosing between fixed and demand responsive policy[25]	MATLAB	2010	To assist planner in the decision making process when having to choose between a demand responsive and fixed-route operating policy and whether and when to switch from one to the other during the day.	The critical demand ranges from 10 to 50 customers/mile^2 and that a demand responsive policy is more preferred during afternoon peak hours
Passenger Agent and Paratransit Operator Reaction to Changes of Service Frequency of a Fixed Train Line[26]	MATSim	2013	To design demand responsive routes and transport networks with enhanced evolutionary model.	Train frequency above 4 minutes for any one train leads an increase in minibuses usage.

2.8 Summary

In this section, we have presented the general status of paratransit in the U.S. We have briefly discussed the challenges as far as the usage of public fixed bus transit services by PWDs. We have briefly discussed some of the remedies that have been implemented to increase public transportation ridership by PWDs, mainly focusing on accessibility and personnel training. Lastly we have presented a literature review of prior research and categorized into two research foci namely, evaluation of paratransit systems using a simulation approach and strategic management decision systems for agencies that offer a combined system of fixed route and demand response transit services. To our knowledge, no research paper has analyzed the status of fixed bus route utilization using real data and simulated the potential for increased ridership by including PWDs who use ADA paratransit services. Our research seeks to fill this gap by simulating the fixed bus route service to the two post visited destinations in Milwaukee County by PWDs and determining the ridership improvement and performance implications when potential riders (who currently use the ADA paratransit) are added to the fixed bus route service simulation model.

Chapter 3 Data Collection

In this chapter, we will present data that was provided to us by the Milwaukee County Office for Persons with Disabilities as well as MCTS-Transit Plus Program. First, we will present bus ridership by passenger with ADA qualification using the fixed bus routes 14, 23 and the Blue line, which serves the destination of interest in this study, namely, the Potawatomi Casino and the V.A. medical center. Secondly, we will present data provided to us by the MCTS-Transit Plus Program regarding ridership of the two contracted van service providers, namely Transit Express and First Transit. In this study, we are restricted to consider paratransit van riders who dialed-in for service to and from the two destinations of interest. Thus, the study data excludes services that were offered without prior reservation.

The MCTS development plan (2010) acknowledges that since year 2000, there has been an increase of total expenditure in the Transit Plus Program (TPP) as well as the ADA fixed-route. Furthermore the increase in the TPP has been twice as much as the increase in the ADA fixed bus route system's expenditure. Moreover, the plan indicates that "such increases in paratransit costs could draw local funding away from the fixed-route bus system if they continue in the future. This would increase the potential for service cuts and fare increases for the bus system, particularly in the absence of dedicated local funding. [14] In this study we focus our analysis on the three bus routes that serve the two mostly visited destinations as follows: MCTS bus route 14(R14)—serving Potawatomi Hotels and Casino and routes Blue and 23(RBlue & R23), both of which serve the V.A. Hospital. Also, we will present data for the Transit Plus Program for both Transit Express (northern regions) and First Transit (southern region).

3.1 Fixed-route Data

3.1.1 Ridership Status in Milwaukee: Both V.A. and Casino Destinations

3.1.1.1 Ridership Data to the V.A. Medical Hospital

Figure 13 and 14, the maximum ADA riders per day for the South and North-bound R23, which serves the V.A. medical hospital. As expected, the summer months between May and July, registered the most ridership, with a summer average ridership of 11 ADA passengers. On the other hand, winter months (December to Feb) registered the least ridership as expected with an average of 3 riders a day.

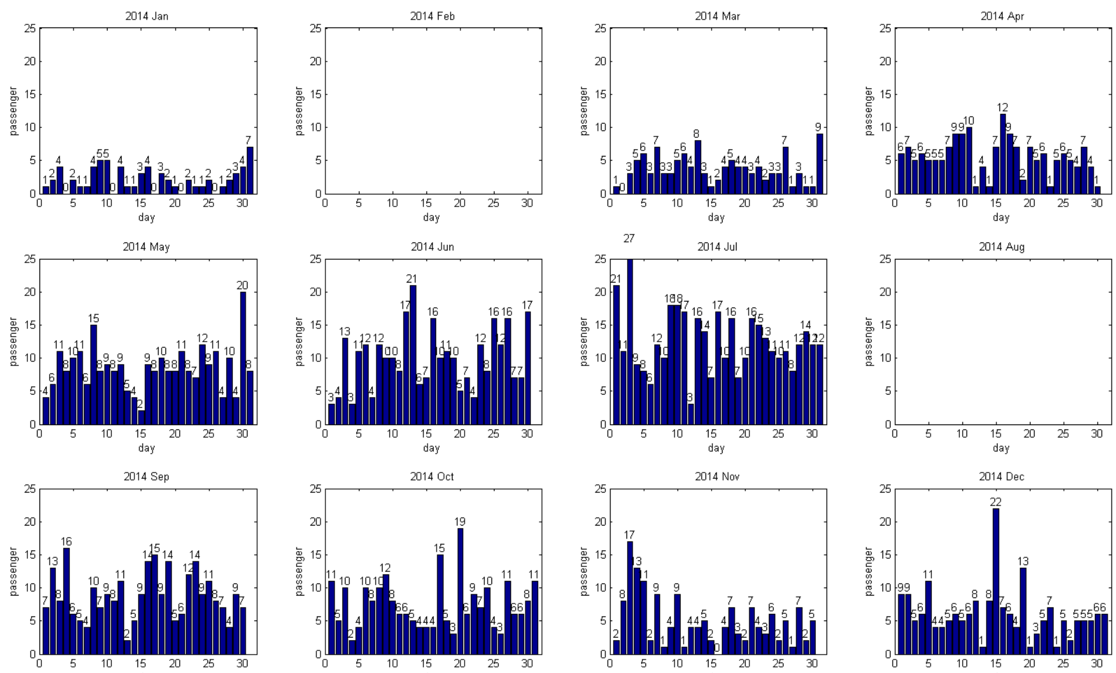


Figure 13 2014-R23-Daily ADA Ridership-North

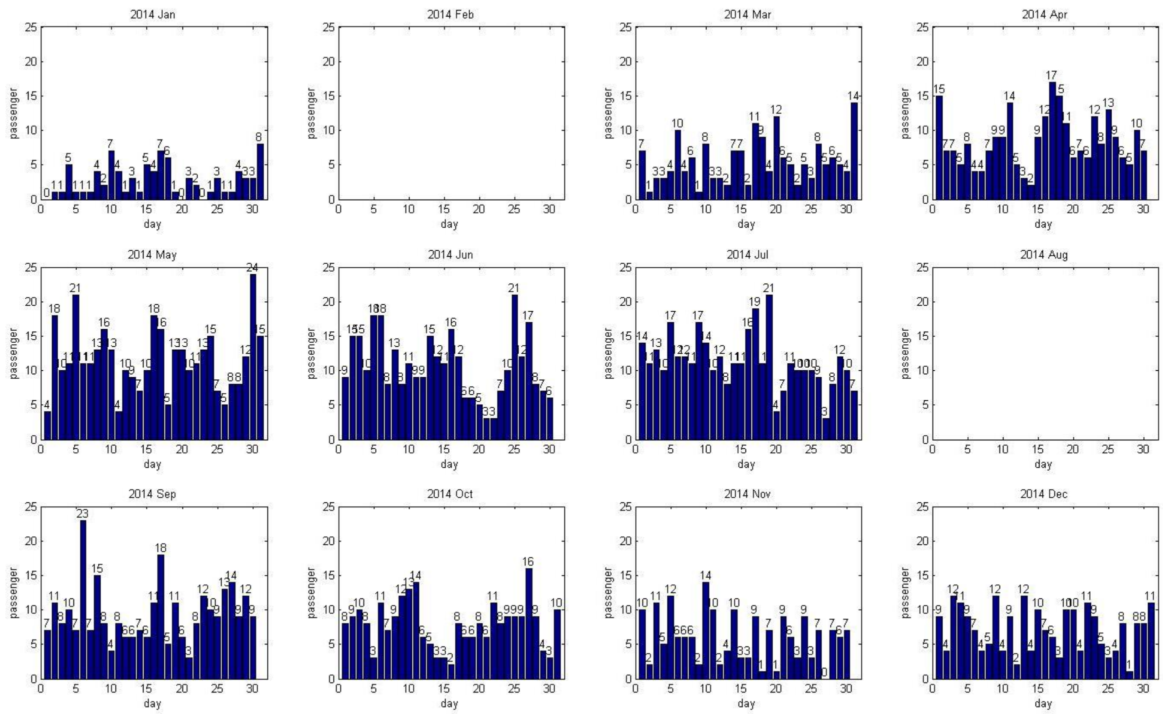


Figure 14 2014-R23-Daily ADA Ridership-South

Figures 15 and 16 present ridership of the north and South-bound RBlue, which also serves the V.A. medical center. Once again, the summer months registered higher ridership with an average of 13 ADA passengers.   Similar to R23, winter months ridership averaged at 3 riders a day.

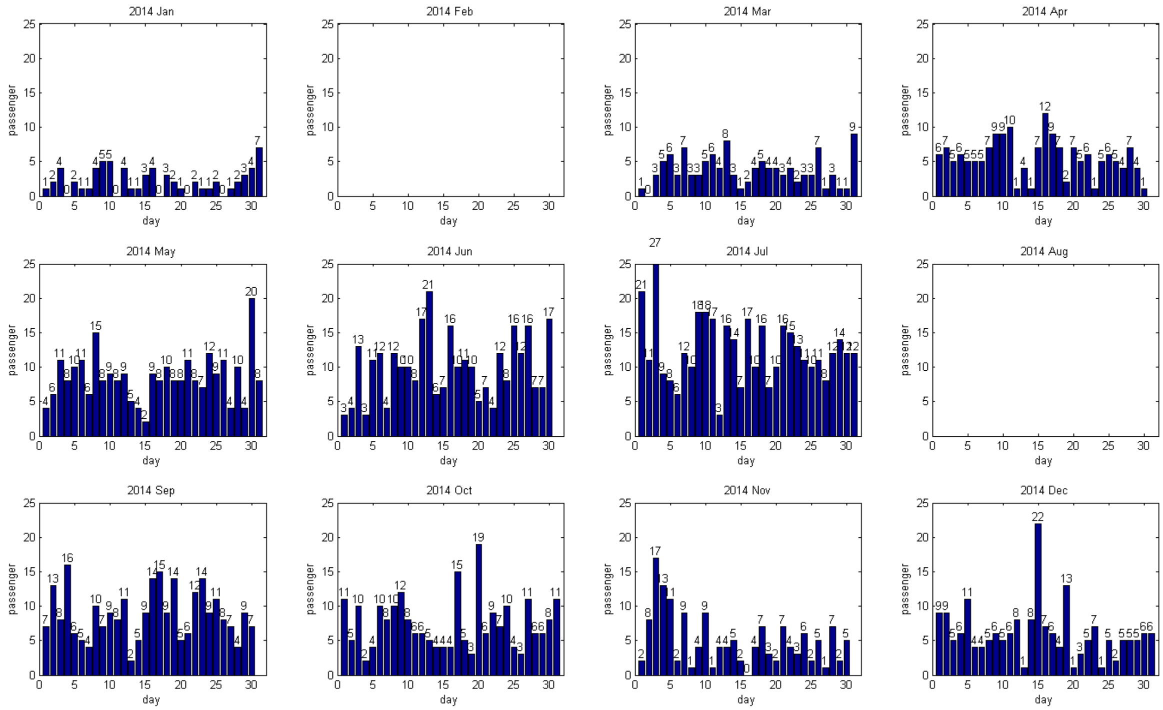


Figure 15 2014-RBlue-Daily ADA Ridership-North

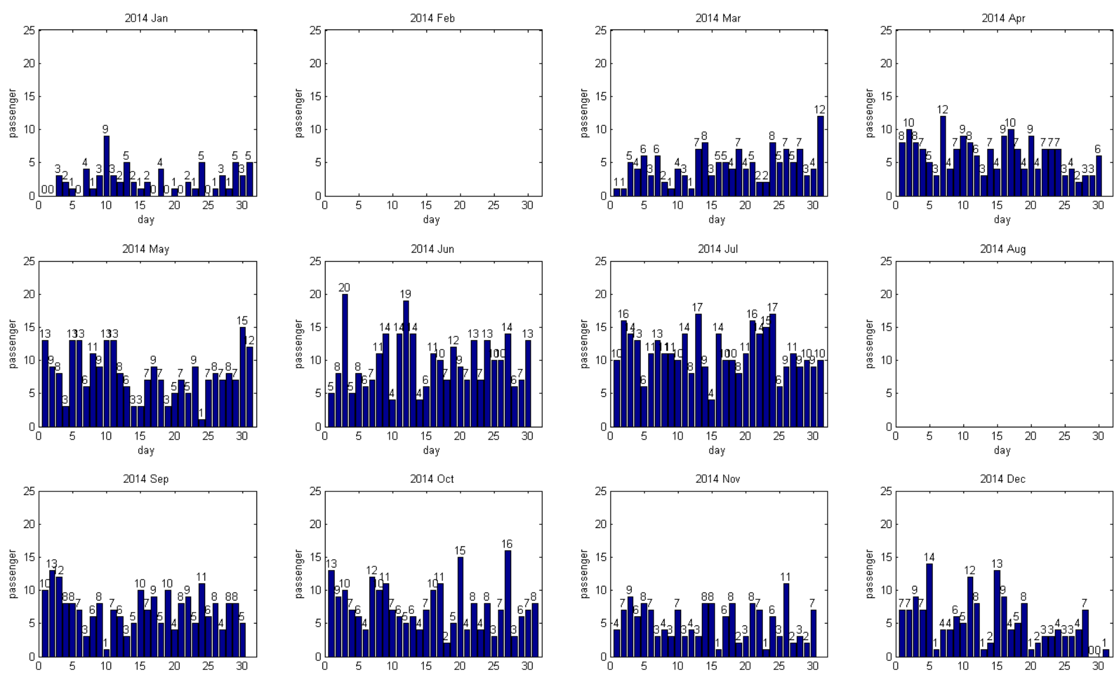


Figure 16 2014-RBlue-Daily ADA Ridership-South

3.1.1.2 Ridership Data to the Potawatomi Hotel and Casino

A similar seasonality of ridership is presented for north and South-bound R14 which serves the Casino as shown in Figures 17 and 18

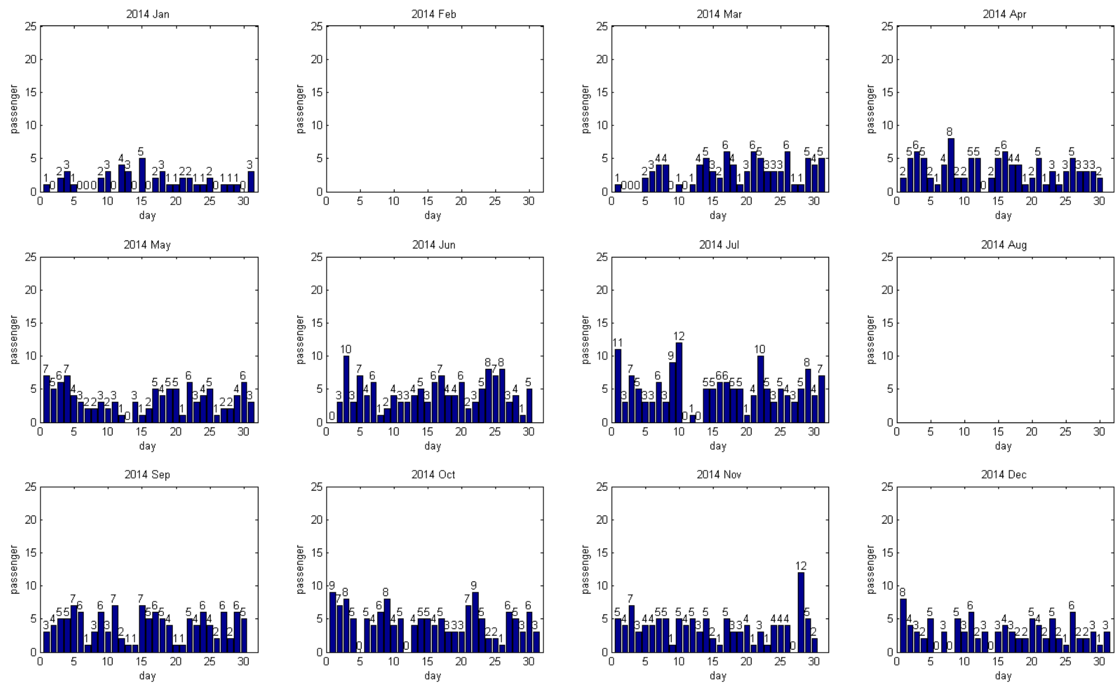


Figure 17 2014-R14-Daily ADA Ridership-North

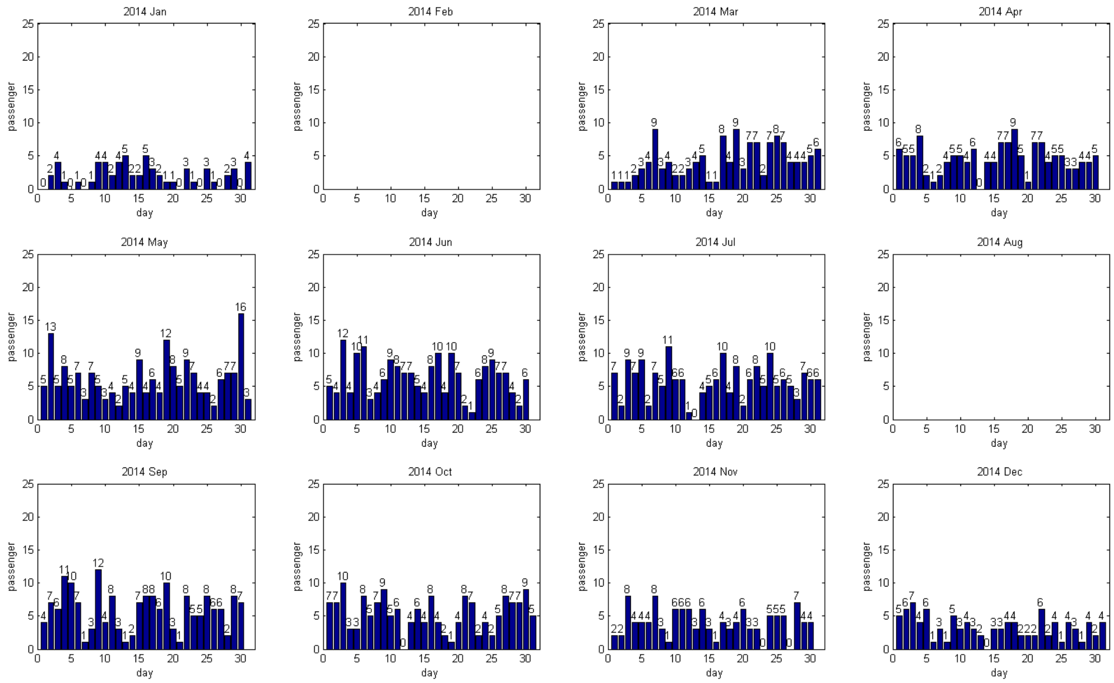


Figure 18 2014-R14-Daily ADA Ridership-South

Even though summer months registered a slightly higher average ridership per day (5 ADA passengers a day), this average is not markedly higher than the winter months ridership (2 ADA passengers per day). It is noticeable that ridership of the fixed bus route service to the Casino is much lower than ridership to the V.A. hospital, by about 6 to 7 riders on average per day. As can be seen in R14 graphs, ridership is quite uniform between March and November, with a reduction between December and January. We wish to emphasize that visits to the Casino would be much better if a more accesses and a user-friendly environment was present at the Casino stops.

3.1.2 Accessibility Observations

3.1.2.1 Accessibility Observations at the V.A. Bus Stop

Observations were made in March 2015 to determine accessibility and overall the environment at the V.A. Medical Hospital bus stop. The R23 and RBlue are the two routes that service the VA hospital. As Figures 19 and 20 presents, we found out the bus stop is close to the gate of V.A Medical Center on either side of the road for the north and south bound routes. Moreover, a ramp has been designed and built for wheelchair users on and off the curb. The slope of the road is quite moderate to enable PWDs on wheelchair or scooter easy access into the building.

Figure 19 V.A. Medical Center Bus Stop (I)

Figure 20 V.A. Medical Center Bus Stop (II)

3.1.2.2 Accessibility Observations at the Casino Bus Stop

Similar to the V.A. destination, observations were made in March 2015 to determine accessibility and overall environment at the Casino bus stop. The R14 bus stop was constructed on the bridge on 16th Street as shown in Figures 21 and 22. Particularly, Figure 21 shows the relative position of the bridge with respect to the Casino.

Figure 21 Less Accessibility for PWDs Passenger: Bus Stops are on the Bridge

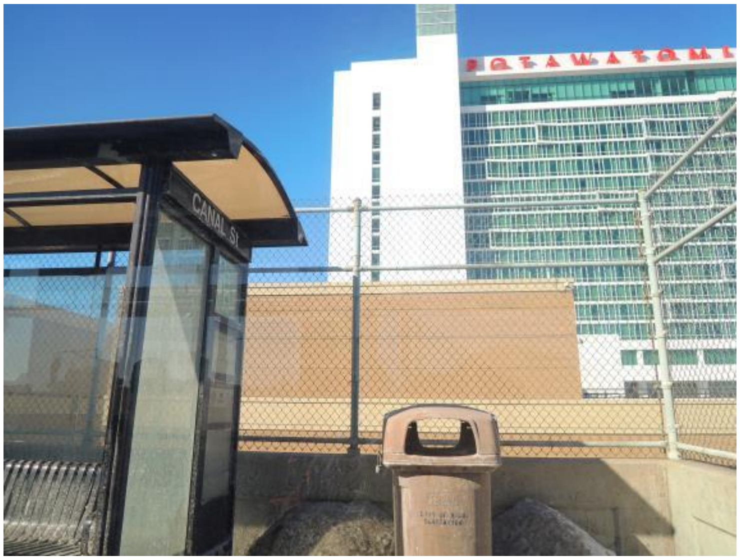


Figure 22 Close-Up Shot of the Bus Stop

Regularly, customer has two ways to exit the bridge toward Casino. Firstly, via steel staircase down to the casino access as shown in Figure 23. Secondly, passengers can walk southwards on 16th street towards the access way into the Casino parking lot entrance beside bridge as depicted in Figure 24.

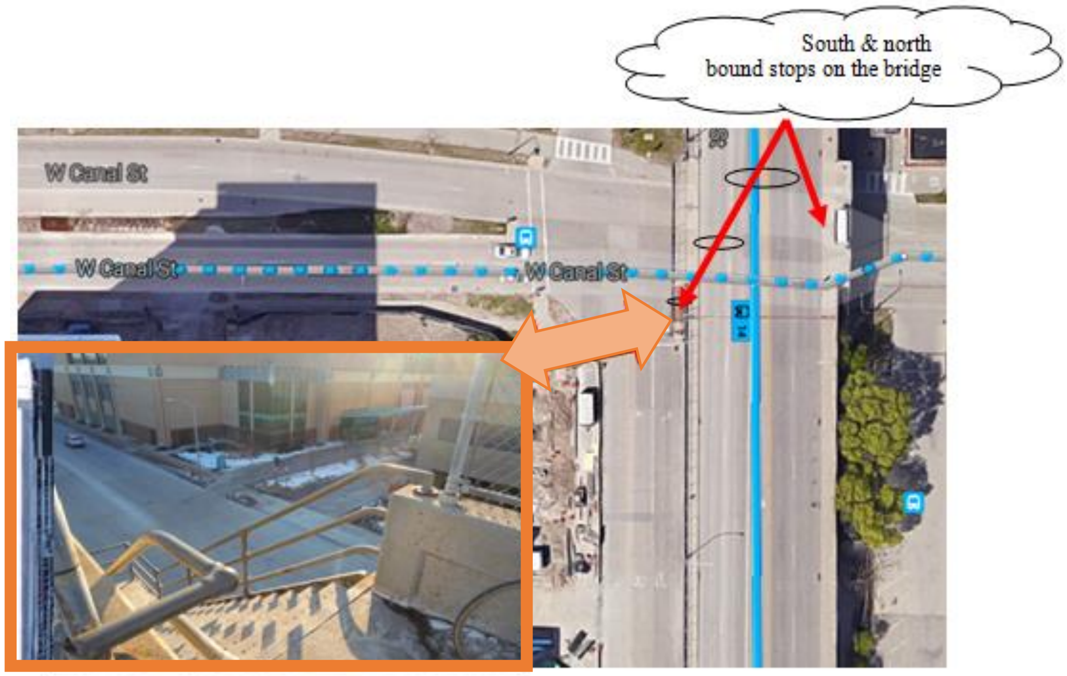


Figure 23 Less accessibility for PWDs passenger: Stair beside the bridge access to the ground level

In addition, the accessibility for north bound PWDs passengers is severely curtailed by the fact that they have to cross 16th street which is brad and quite busy. Also, since PWDs especially those on wheel chairs or scooters cannot use the steel staircase, they are forced to travel southwards along 16th street to access the Casino via the parking lot access way (Figure 23). Moreover, accessibility is lessened during the winter season due to the accumulation of ice and snow-mounds along 16th street as well as the ramp as shown in Figures 24 and 25. Anecdotal information when a few wheelchair users were asked indicates that the pavements are not maneuverable when the snow height is equal to or above 3 inches.

Figure 24 Ice Barrier for Crossing the Street (Red Demarcation Shows the Casino Parking Lot Access Way)

Figure 25 Ice Cover on Street

In general, the design of the Casino bus stop for PWDs passengers is totally unfriendly especially since currently R14 is the only fixed bus route that serves the Casino.

3.2 ADA Paratransit Data (Transit Plus Data)

In this section of the Thesis, we will present the data that was obtained from MCTS-Transit Plus Program regarding ADA paratransit ridership to the Casino and the V.A. hospital using the two subcontracted companies, i.e. Transit Plus and First Transit. This data depicts ridership from May 1st 2014 to April 30th 2015.

3.2.1 Paratransit Service Ridership to the V.A Medical Center

Figures 26 indicate the density of ridership of Transit Express and First Transit.

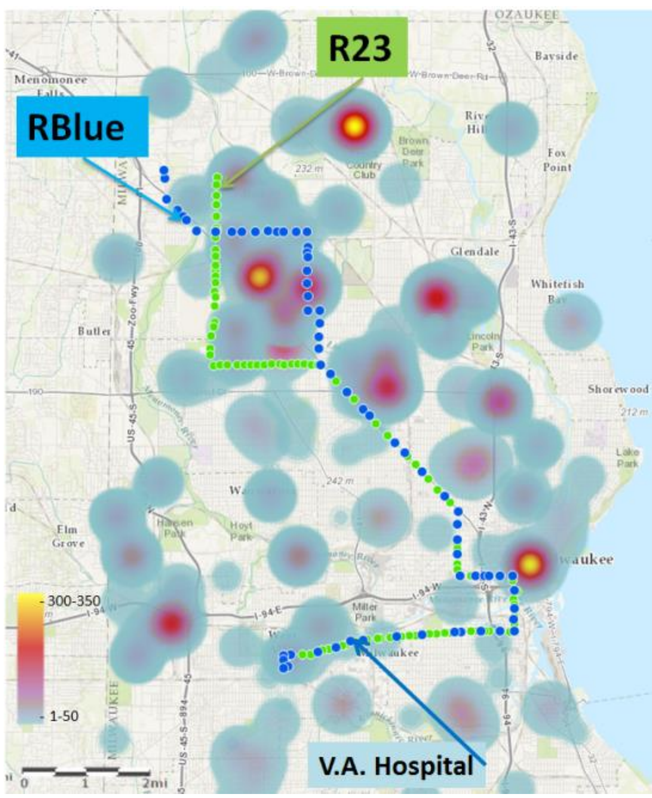


Figure 26 Population Density Graph – To V.A. Hospital

We have superimposed the ridership maps onto the maps indicating routes RBlue and R23 which serve the V.A. hospital. This combination of maps enables us to determine potential ADA paratransit riders who could use the fixed route bus service. The potentiality of a rider was determined by addresses that are geographically positioned less than or equal to 0.5 miles from the bus route. Two assumptions were made for computational purposes: (1) that the road(s) from the specific addresses to the bus routes are completely accessible by any rider, (2) that the PWDs in these locations can access the bus stop. In the Figure 26 we will note that the color density in the circles represent the number of requests that were made from a particular address as shown by the graph legend. This number includes requests by PWDs traveling solo or by PWDs travelling with one or more companions.

As seen in Figures 27 and 28, quite a substantial number of riders leave along the bus routes hence we envision that making the bus service as well as the bus stops more user-friendly as well as creating awareness of the incentives provided by MCTS will increase bus ridership.

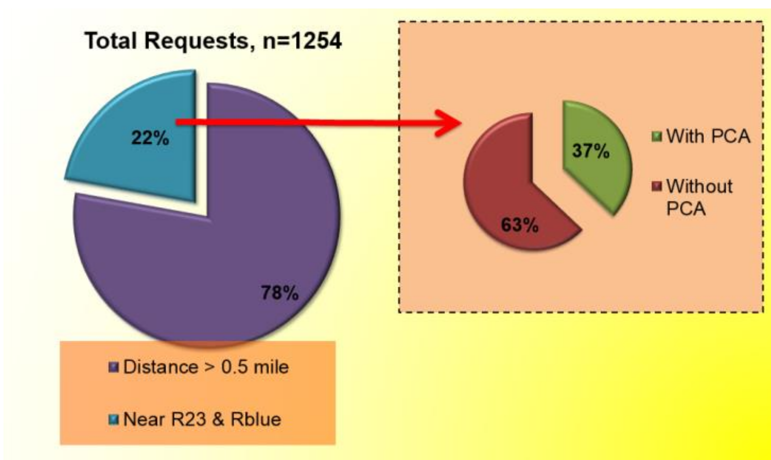


Figure 27 Total Ridership of Transit Express to the V.A. Hospital

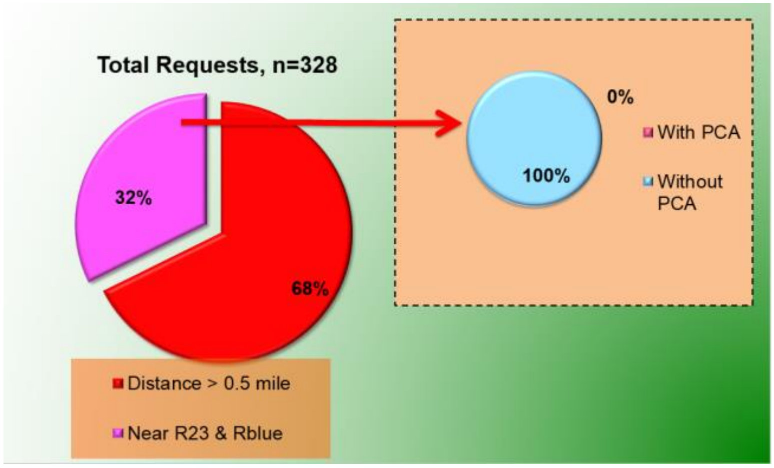


Figure 28 Total Ridership of Transit Express to the V.A. Hospital

3.2.2 Paratransit Service Ridership to the Potowatomi Casino

Similarly, a density map was created of total ridership on the ADA paratransit service to the Potawatomi Casino as shown in Figure 29 .

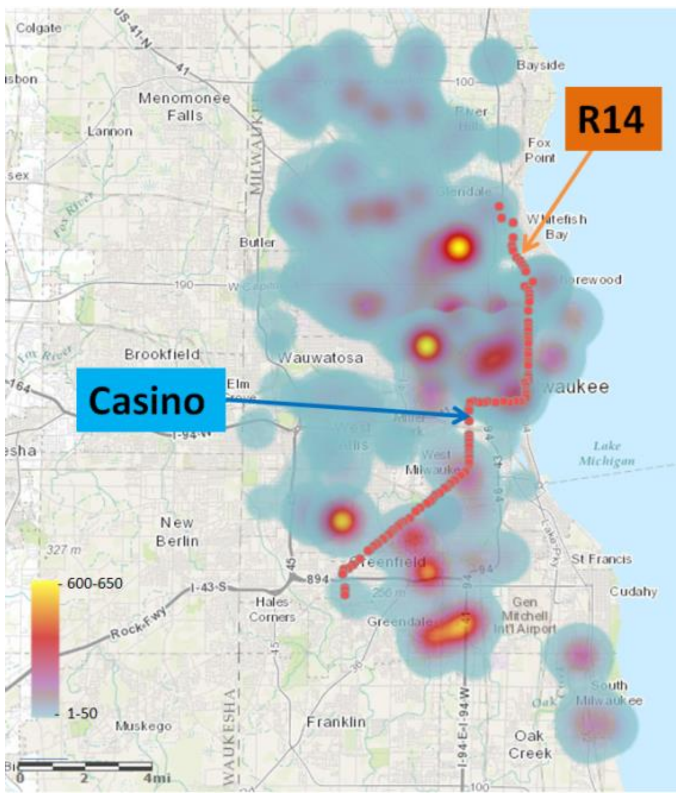


Figure 29 Population Density Graph – To Casino

Once again, the color density represents the total number of solo riders or PWDs with companions from a given address. Though the Thesis did not focus on the entire MCTS network of bus routes, this map could enable MCTS determine geographical areas that would benefit from additional routes.

Figures 30 and 31 indicate the percentage of riders using the two ADA paratransit companies to the Casino.

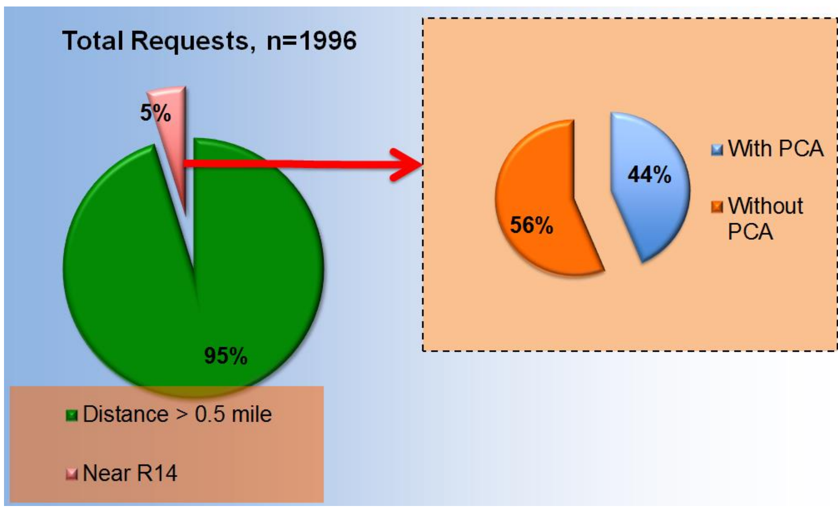


Figure 30 Total Ridership of Transit Express to Casino

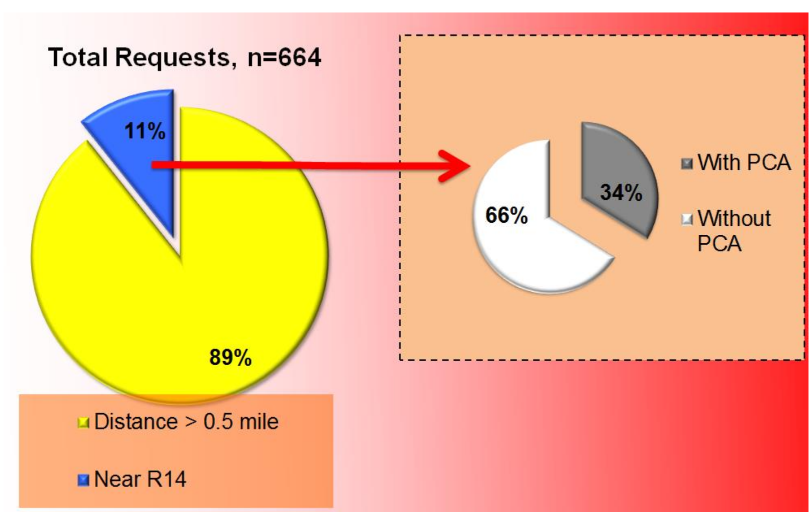


Figure 31 Total Ridership of First Transit to Casino

We have once again curved out the portions of potential riders who could use R14 to the Casino. Compared with the bus routes R23 and RBlue, fewer portions (5% for Transit Express and 11 % for First Transit) of riders residing near R14 bus stops request to use the ADA paratransit service to the Casino. Consequently we predict that R14 bus route does not cover the key sources of potential riders to the Casino especially apartments or condominium complexes that serve a higher percentage of senior citizens. To conserve the privacy of the riders, no proprietary information such as specific locations will be published in this Thesis. As Figure 29 shows, the densest areas with PWDs are mainly located approximately 2 or more miles west of the R14.

Chapter 4 Research Methodology

4.1 Simulation Model (I) – Fixed Bus Routes

In this chapter, the simulation model of the three fixed bus routes that serve the mostly visited destination by PWDs is presented. This routes include, north and south bound R14 (serving the Casino) and north and south bound R23 and RBlue both of which serve the V.A. medical hospital. However, due to time constraints, a simulation model was only built for the former route (R14) that serves the Casino. This destination was chosen since it poses the most challenge for PWDs using the fixed bus route system. As presented earlier, the biggest challenge arises from the current status of the bus stop as well as the fact that only one bus route serves this destination, yet it has the most PWD visitors who currently use the ADA paratransit system. In addition, passengers visiting the Casino have to cross the busy 16th street in order to access the Casino parking lot entry, and walk for approximately 5 minutes to the Casino entrance. This is particularly unfriendly for persons with ambulatory disabilities.

Simulation modeling techniques incorporate physical or computer-based models that are manipulated in such a way as to mimic real world systems performance in space and time domains. Such models enable the analysis of factors and interactive effects that would otherwise not be possible to study from the real world systems. Currently, a considerable number of simulation software has been developed for use in personal computers, with friendly graphical user interfaces. Hence, over the decades, simulation models have thus found tremendous usage in operations research and management of systems in diverse disciplines including healthcare, logistics, manufacturing, and transportation.

In this study, the simulation model was built and implemented using ProModel software version 8.6. ProModel is a discrete-event simulation software used to plan, design and improve new and existing production and service systems. Besides ProModel, the second other mostly used software is Arena. Both software have great features available for building up the simulation models. Both need very little programming capabilities on the side of the user, since they both have built-in simulation operation functions. The choice of ProModel in this study was purely based on accessibility in the computer labs. Figure 32 presents the ProModel procedure that was followed in this study.

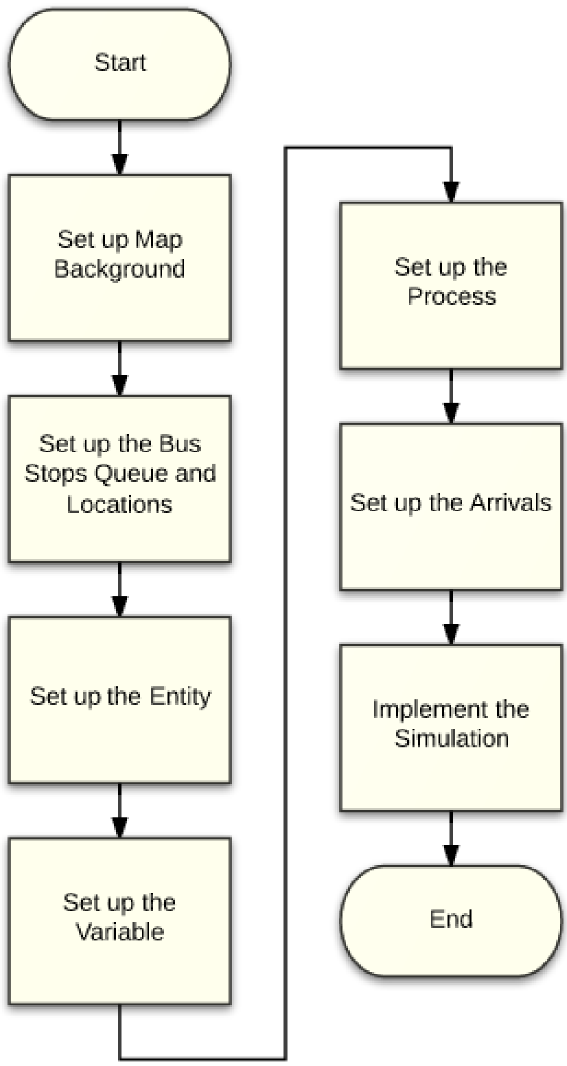


Figure 32 Simulation Establish Procedure

4.1.1 Model Background

So as to build up a network that is as realistic as possible, the distance between each bus stop on R14 was calculated using Google Maps. Similarly, the bus route as it appears in the MCTS website was imported and superimposed onto Google Maps as the background of the simulation model as shown in Figure 33.

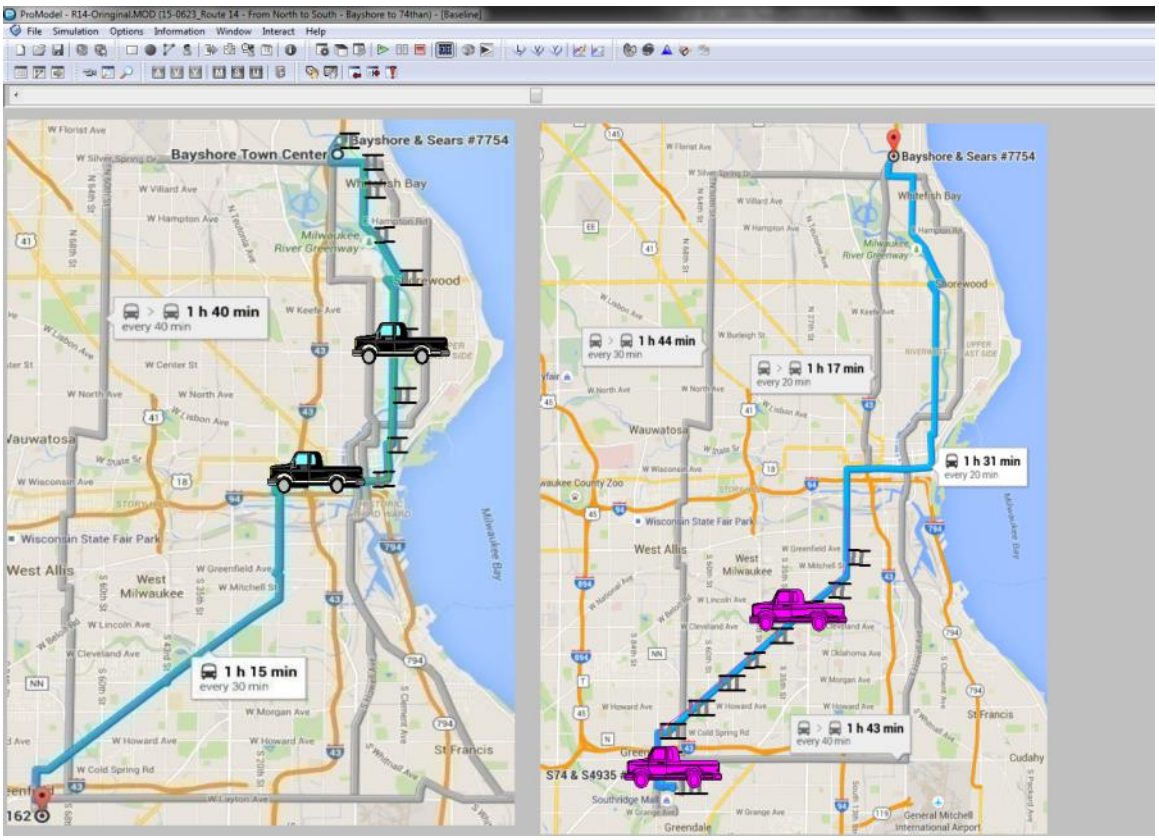


Figure 33 ProModel R14 Simulation Model-Background

4.1.2 Bus stops location

At the same time, the bus routing information we set up in simulation network is a replica of the one in the MCTS official website. To remedy the chance of having too many bus stop in the simulation model, we deliberately combined bus stops that were within a mile of the key bus stops indicated in the MCTS route map. For instance, R14 has a total of 115 actual bus stops along the route. The MCTS R14 map shows about 11main stops. By combining the extant key stops with the 1 mile location radius, we resolved to have 21 bus stops (11 in the north and 10 in the south bound regions) as illustrated in Figure 34, which is a screen shot of the simulated bus stops in ProModel.

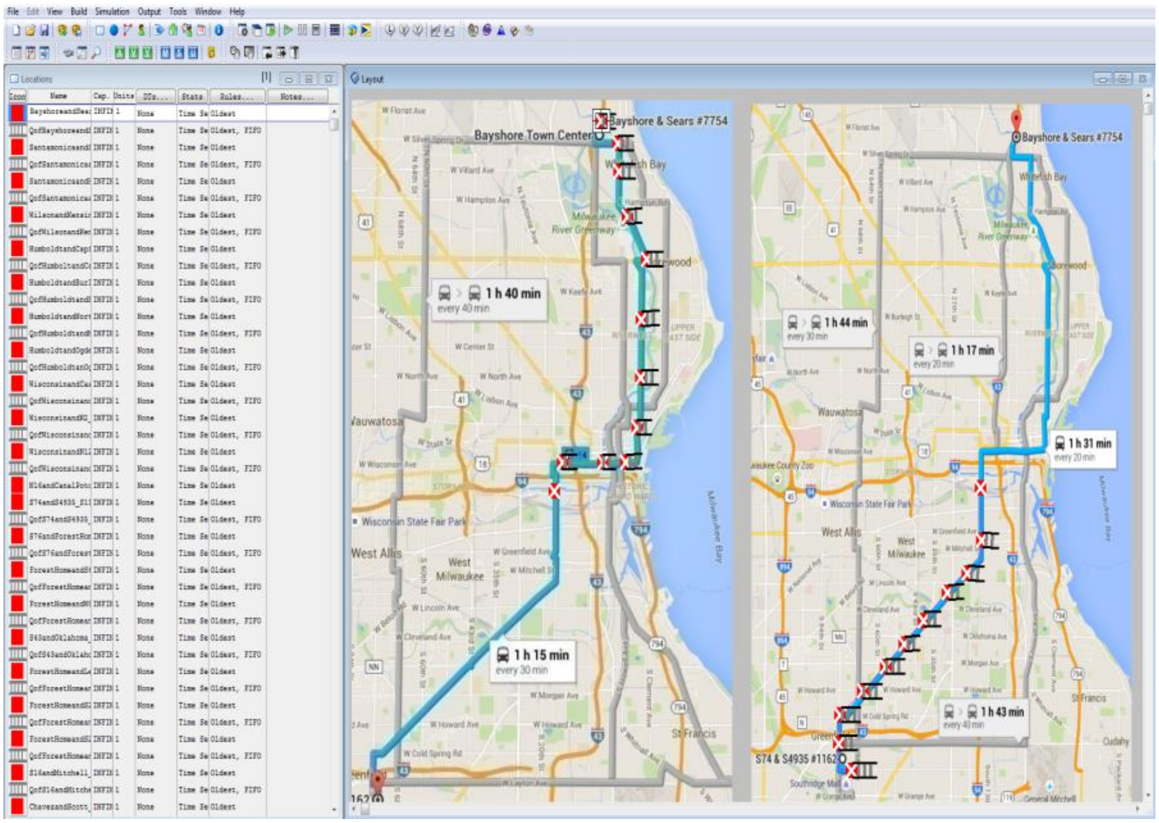


Figure 34 ProModel R14 Simulation Model-Location

4.1.3 Passenger and Bus Entities

PWDs Passenger

Considering the passenger with ambulatory disabilities, their movement is aided by using either one or two walking sticks, crutches or other assistive devices such as the rollator walker, wheelchair or scooter. In this simulation, we therefore categorized ambulatory disabled PWDs as shown in Table 7. Also, Figure 35 presents the screen shot of the entities set up in ProModel.

Table 7 Attributes of PWDs passenger

Attributes of PWDs passenger		**Entity**
1.	Wheelchair or scooter users	*Passenger With Wheelchair*
2.	Walking stick, crutch or rollator walker and other without assistant device	*Passenger*

Bus Vehicle

Considering the number of north and south bound bus runs, we create one entity for each run in the simulation model. Moreover, we distinguish north bound group and south bound group using the nomenclature shown in Table 8.

Table 8 Bus Entity Setting

North Bound	Take off time	Entity
	6:03 AM	*BusN8*
	6:11 AM	*BusN9*
	6:06 AM	*BusN10*
	6:23 AM	*BusN11*
	…	…
South Bound	6:00 AM	*BusS5*
	6:06 AM	*BusS6*
	6:06 AM	*BusS7*
	6: 24 AM	*BusS8*
	…	…

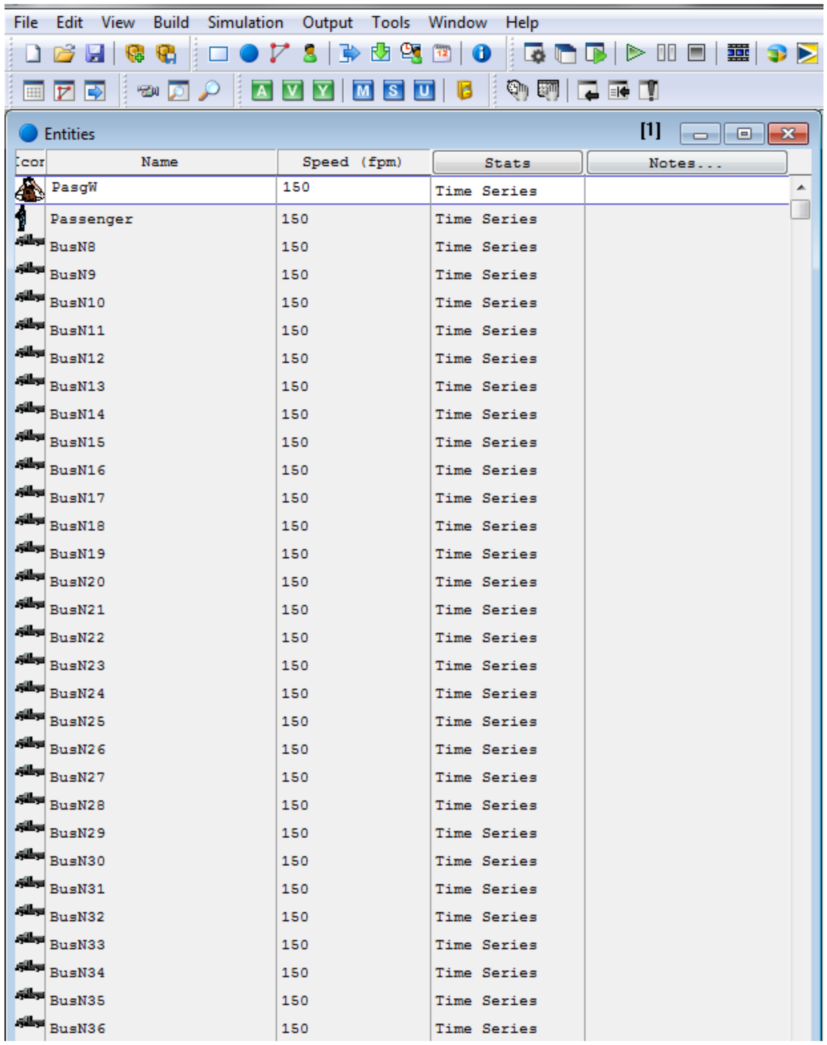


Figure 35 ProModel R14 Simulation Model-Entities

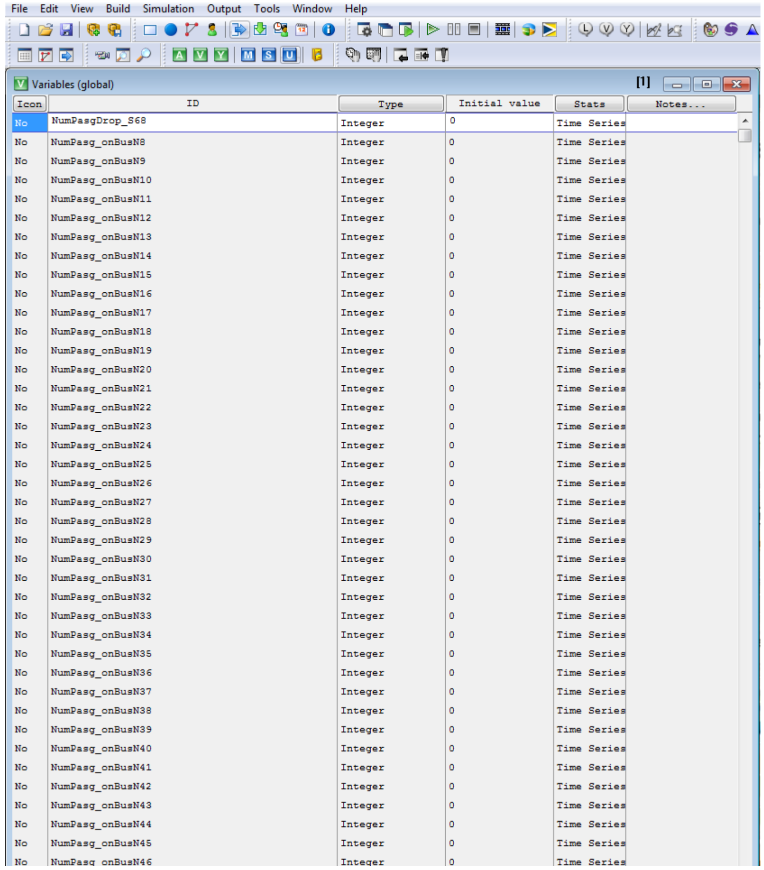
4.1.4 Variables and Parameters

The creation of variables and parameters is useful in any simulation model for enabling effective data collection as well as analysis. The main distinction is that, the process variables can be observed and are stochastic during the simulation process. On the other hand, system parameters are usually unknown but can be estimated as a result of several iterations/runs of the models. Thus, in this model, variables include number of passengers in the system who have boarded a bus at any one time, the number of passengers in the bus stops at a given simulation time, and the number of passengers in the system who have reached their destination. System parameters that will be estimated in this model include average bus utilization, average number of

PWDs who has to wait for another bus, average number of ambulatory PWDs who could not get onto the bus due to wheelchair capacity constraints, the average waiting time of PWDs and average waiting time of ambulatory PWDs with mobility devices (wheelchairs and scooters) in the system. Table 9 summarizes the description for each variable as well as the system constraints. Figure 36 shows the screen shot of variable setting in ProModel.

Table 9 Simulation Variables and Constrain

Variable	**Process Tally**	**Attribute Description**
$x_{Attribute\_of\_PWDs,Bus}$	Number of passengers who have boarded a bus at a given simulation time	$Attribute\_of\_PWDs \in$ {Passenger, Passenger with Wheelchair} $Bus \in$ {BusN8, BusN9, BusN10… BusS6, BusS7, BusS8…}
$y_{Attribute\_of\_PWDs,Bus\_Stop}$	Number of passengers at the bus stop at a given simulation time	$Attribute\_of\_PWDs \in$ {Passenger, Passenger with Wheelchair} $Bus\_Stop \in$ {Stop1, Stop2, …}
z	Number of passengers dropped off at the destination	
Constraint		
Bus_Capacity	Bus capacity for wheelchair user	



Icon	ID	Type	Initial value	Stats	Notes...
No	NumPasgDrop_S68	Integer	0	Time Series	
No	NumPasg_onBusN8	Integer	0	Time Series	
No	NumPasg_onBusN9	Integer	0	Time Series	
No	NumPasg_onBusN10	Integer	0	Time Series	
No	NumPasg_onBusN11	Integer	0	Time Series	
No	NumPasg_onBusN12	Integer	0	Time Series	
No	NumPasg_onBusN13	Integer	0	Time Series	
No	NumPasg_onBusN14	Integer	0	Time Series	
No	NumPasg_onBusN15	Integer	0	Time Series	
No	NumPasg_onBusN16	Integer	0	Time Series	
No	NumPasg_onBusN17	Integer	0	Time Series	
No	NumPasg_onBusN18	Integer	0	Time Series	
No	NumPasg_onBusN19	Integer	0	Time Series	
No	NumPasg_onBusN20	Integer	0	Time Series	
No	NumPasg_onBusN21	Integer	0	Time Series	
No	NumPasg_onBusN22	Integer	0	Time Series	
No	NumPasg_onBusN23	Integer	0	Time Series	
No	NumPasg_onBusN24	Integer	0	Time Series	
No	NumPasg_onBusN25	Integer	0	Time Series	
No	NumPasg_onBusN26	Integer	0	Time Series	
No	NumPasg_onBusN27	Integer	0	Time Series	
No	NumPasg_onBusN28	Integer	0	Time Series	
No	NumPasg_onBusN29	Integer	0	Time Series	
No	NumPasg_onBusN30	Integer	0	Time Series	
No	NumPasg_onBusN31	Integer	0	Time Series	
No	NumPasg_onBusN32	Integer	0	Time Series	
No	NumPasg_onBusN33	Integer	0	Time Series	
No	NumPasg_onBusN34	Integer	0	Time Series	
No	NumPasg_onBusN35	Integer	0	Time Series	
No	NumPasg_onBusN36	Integer	0	Time Series	
No	NumPasg_onBusN37	Integer	0	Time Series	
No	NumPasg_onBusN38	Integer	0	Time Series	
No	NumPasg_onBusN39	Integer	0	Time Series	
No	NumPasg_onBusN40	Integer	0	Time Series	
No	NumPasg_onBusN41	Integer	0	Time Series	
No	NumPasg_onBusN42	Integer	0	Time Series	
No	NumPasg_onBusN43	Integer	0	Time Series	
No	NumPasg_onBusN44	Integer	0	Time Series	
No	NumPasg_onBusN45	Integer	0	Time Series	
No	NumPasg_onBusN46	Integer	0	Time Series	

Figure 36 ProModel R14 Simulation Model-Variable

4.1.5 Process setting

Bus Route and Passenger Settings

In this model, we assume, for the sake of computation, that buses enter the system through the first bus stop, and take off from the system using the bus stop that is closest to the destination. Figure 37 shows the screen shot of the route setting in ProModel.

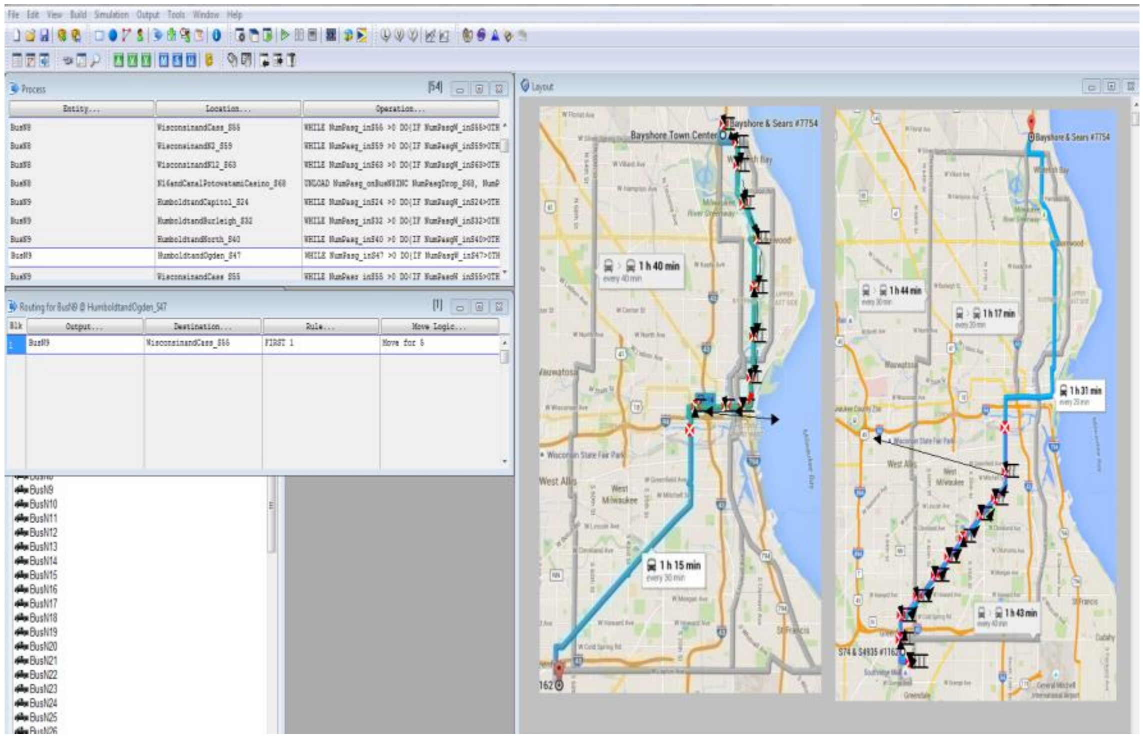


Figure 37 ProModel R14 Simulation Model-Bus Process

On the other hand, we assign attributes to every passenger in the system at the bus stop queue and serve them on a first-come-first-serve basis, as long as the bus capacity is not reached. In addition, we assume each passenger boards at the time, thus the model has no simultaneous arrivals.

PWDs Passenger Boarding Procedure

Boarding procedure is shown in the Figure 38, whenever a bus visit at a bus stop, the boarding logic will be triggered to determine the allowable loading number of passengers; especially for wheelchair users whose capacity is set at two per bus, similar to the real situation in the MCTS buses.

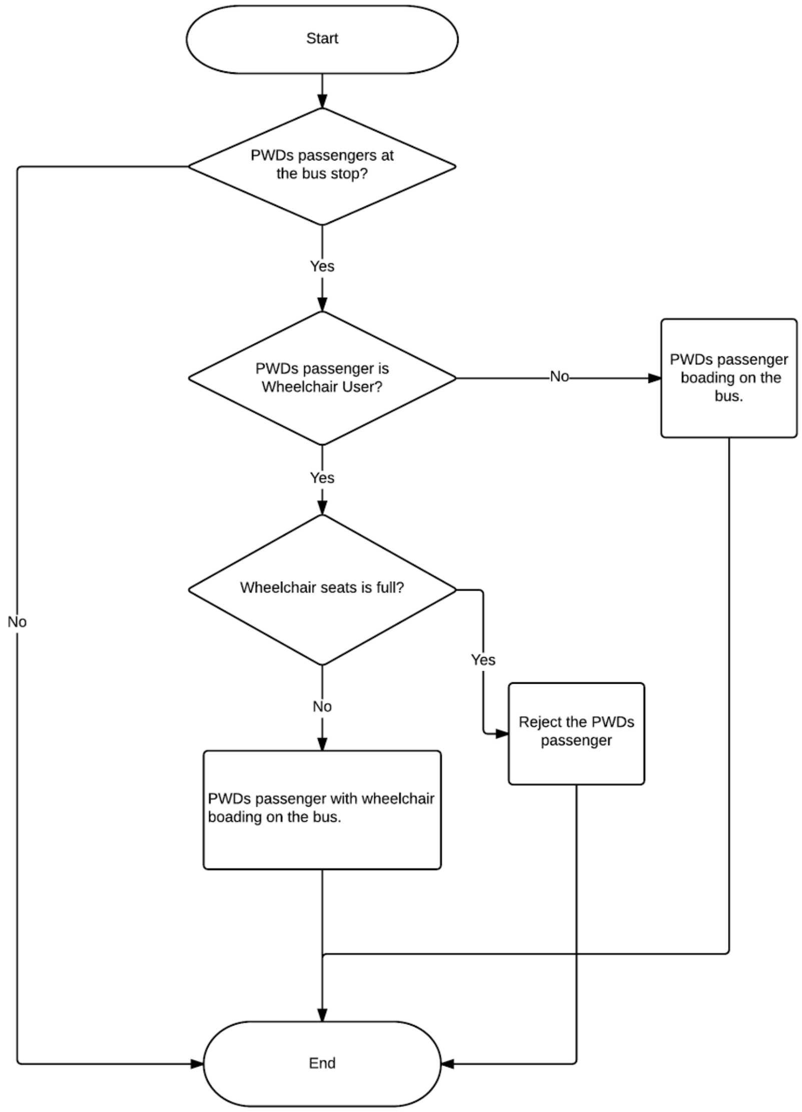


Figure 38 Passenger Boarding Procedure

4.1.6 Passenger Arrivals Generation Procedure

Arrival Time Allocation

With the intention of generating the PWDs passenger as realistic as possible, two primary attributes are considered for each passenger. According to the pre-processing results of data from the two Transit Plus, van companies (Transit Plus and First Transit), the earliest service request time is 8:00 AM and the latest 8:30 PM. In this study, we infer that fixed bus route PWDs users also have a similar travel requirement. Therefore, we set up the simulation time schedule to cover the earliest and latest service request times. Moreover, assuming PWDs users begin to head to the Casino at or after 6:00 AM, then 6:00 AM is adopted as the starting time of the passenger arrival to the assigned R14 bus stop. Likewise, 9:00 PM is determined to be the latest time for boarding heading to the Casino. Secondly, according to the time table of R14 bus schedule, the bus frequency in each hour is different, so in this study, we used real R14 annual ridership data to calculate the percentage distribution of PWDs in the system as shown in Table 10.

Table 10 Percentage of Passenger Arrival in Different Time Segment

Time period	Percentage of Passengers Arrival
6:00 - 7:30	30%
7:31 - 13:00	20%
13:01 - 16:30	30%
16:30 - 21:00	20%

Passenger Bus Stop Allocation

We assign point of origin (bus stop) to each passenger randomly following a uniform distribution. Thus a passenger arriving into the system is randomly assigned to the 11 north bound or 10 south bound bus stops along R14 bus route as shown in Table 11

Table 11 Representative Number for R14 Bus Stop

North Bound Stop	Representative Number	South Bound	Representative Number
Bayshore & Sears	1	S74 & S4935	1
Santamonica & SilverSpring	2	S76 & ForestHome	2
Santamonica & Henryclay	3	ForestHome & S68	3
Wilson & Kensington	4	ForestHome & W54	4
Humbolt & Capitol	5	S43 & Oklahoma	5
Humboldt & Burleigh	6	ForestHome & Leeds	6
Humboldt & North	7	ForestHome & S27	7
Humboldt & Ogden	8	ForestHome & S20	8
Wisconsin & Cass	9	S16 & Mitchell	9
Wisconsin & N2	10	Chavez & Scott	10
Wisconsin & N12	11		

Passenger Attributes

The main passenger binary attribute that matters most in this model is mobility type i.e passenger with or without a wheelchair. To make this assignment we also base the proportions following read data from the Transit Plus bus companies. In which case, about 43.4% passengers use wheel chairs as illustrated in Figure 39.

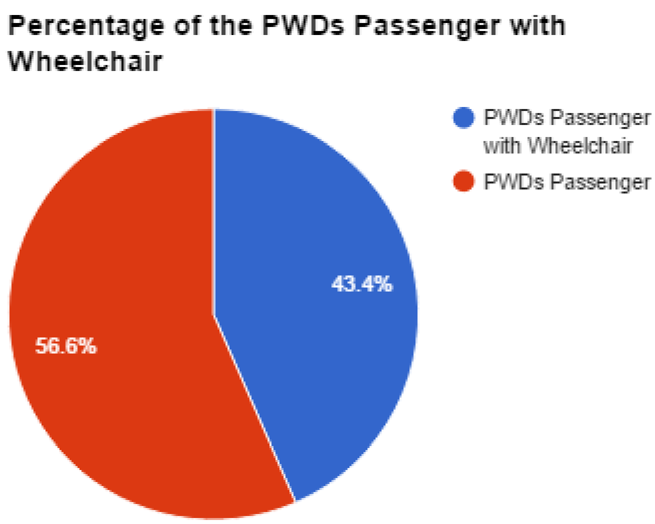


Figure 39 Percentage of the PWDs Passenger with Wheelchair

Seasonality in Ridership

The ADA fixed bus route rider boarding data presented previously in chapter 3 provided monthly ridership totals. First, in this study, the monthly ridership is consolidated as shown in Table 12 to represent seasonal ridership. This consolidation is particularly favorable since some months' data is missing.

Table 12 Define the Months to the Season

Season	Month
Spring	March, April, May
Summer	June, July, August
Fall	September, October, November
Winter	December, January, February

Second, we average the ridership on each day (assumed 30-day months) for each same season to get the general idea about the ridership performance across days within each season. The idea is shown in Table 13. Third, the data of ridership each day does not provide details regarding the proportion of riders whose destination is the Casino. Hence, we arbitrarily chose to assume that 60% of riders are destined for Casino stop. The Figure 40 presents the 60% average ridership for the different season whose destination is the Casino. Figure 41 shows the screen shot of the passenger arrivals setting in ProModel.

Table 13 Ridership in Season Aspect

Spring	March	April	May	Average Ridership
Day 1	1	6	5	4
Day 2	1	5	13	7
Day 3	1	5	5	4
…	…	…	…	…
Day 30	5	6	16	9

Figure 40 R14-60% Ridership in Different Seasons

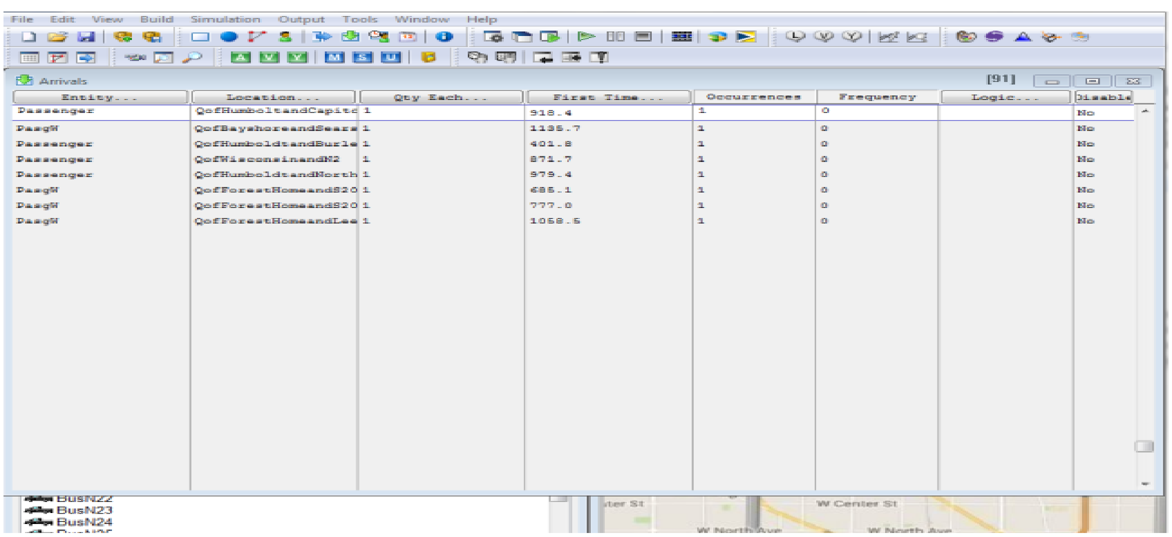


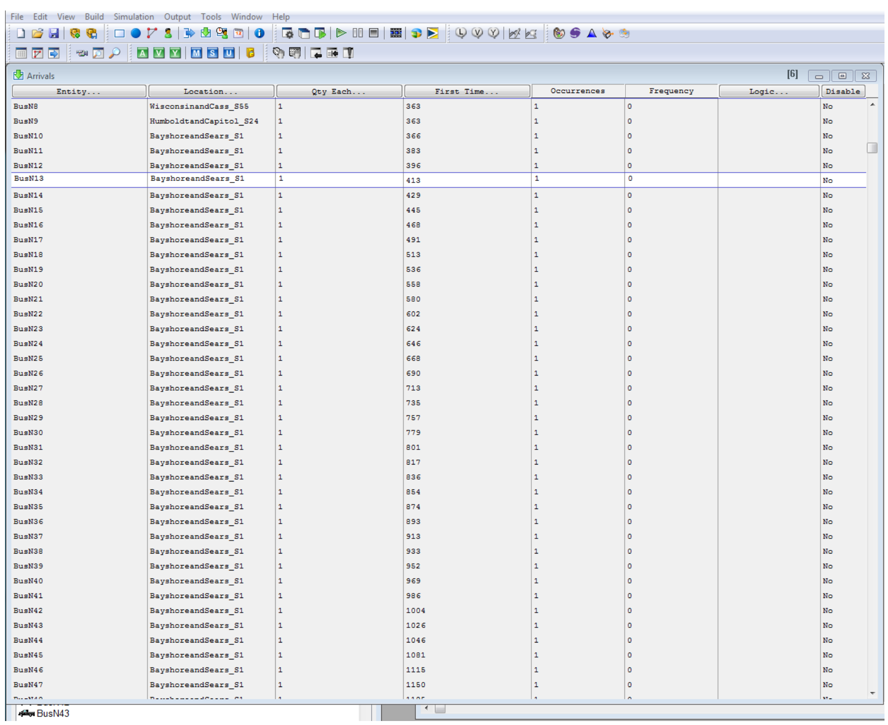
Figure 41 ProModel R14 Simulation Model-Passenger Entity Arrivals

4.1.7 Bus Arrivals to the Casino Stop

The bus arrival time strictly follow the schedule provided by MCTS. Most of buses start from the north most and south most stop. Thus in the case of R14, the north most is the *Bayshore Mall stop* while the south most stop is at the intersection of *S74 & S4935*. However, to ensure that passengers assigned to stops downstream or upstream (of the south bound and north bound directions respectively) do not wait for much longer times, a few buses are deliberately assigned starting points on other stops along the route. Such as assignment is illustrated in Table 14. Figure 42 is the screen shot of the bus arrival setting in ProModel.

Table 14 Bus Entities Arrival Information

Entity	Location(Bus Stop)	Arrival Time
BusN8	Wisconsin & Cass	6:03 AM
BusN9	Humboldt & Capitol	6:03 AM
BusN10	Bayshore & Sears (North bound stop)	6:06 AM
BusN11	Bayshore & Sears (North bound stop)	6:23 AM
…	….	…



Entity...	Location...	Qty Each...	First Time...	Occurrences	Frequency	Logic...	Disable
BusN8	WisconsinandCass_S55	1	363	1	0		No
BusN9	HumboldtandCapitol_S24	1	363	1	0		No
BusN10	BayshoreandSears_S1	1	366	1	0		No
BusN11	BayshoreandSears_S1	1	383	1	0		No
BusN12	BayshoreandSears_S1	1	396	1	0		No
BusN13	BayshoreandSears_S1	1	413	1	0		No
BusN14	BayshoreandSears_S1	1	429	1	0		No
BusN15	BayshoreandSears_S1	1	445	1	0		No
BusN16	BayshoreandSears_S1	1	468	1	0		No
BusN17	BayshoreandSears_S1	1	491	1	0		No
BusN18	BayshoreandSears_S1	1	513	1	0		No
BusN19	BayshoreandSears_S1	1	536	1	0		No
BusN20	BayshoreandSears_S1	1	558	1	0		No
BusN21	BayshoreandSears_S1	1	580	1	0		No
BusN22	BayshoreandSears_S1	1	602	1	0		No
BusN23	BayshoreandSears_S1	1	624	1	0		No
BusN24	BayshoreandSears_S1	1	646	1	0		No
BusN25	BayshoreandSears_S1	1	668	1	0		No
BusN26	BayshoreandSears_S1	1	690	1	0		No
BusN27	BayshoreandSears_S1	1	713	1	0		No
BusN28	BayshoreandSears_S1	1	735	1	0		No
BusN29	BayshoreandSears_S1	1	757	1	0		No
BusN30	BayshoreandSears_S1	1	779	1	0		No
BusN31	BayshoreandSears_S1	1	801	1	0		No
BusN32	BayshoreandSears_S1	1	817	1	0		No
BusN33	BayshoreandSears_S1	1	836	1	0		No
BusN34	BayshoreandSears_S1	1	854	1	0		No
BusN35	BayshoreandSears_S1	1	874	1	0		No
BusN36	BayshoreandSears_S1	1	893	1	0		No
BusN37	BayshoreandSears_S1	1	913	1	0		No
BusN38	BayshoreandSears_S1	1	933	1	0		No
BusN39	BayshoreandSears_S1	1	952	1	0		No
BusN40	BayshoreandSears_S1	1	969	1	0		No
BusN41	BayshoreandSears_S1	1	986	1	0		No
BusN42	BayshoreandSears_S1	1	1004	1	0		No
BusN43	BayshoreandSears_S1	1	1026	1	0		No
BusN44	BayshoreandSears_S1	1	1046	1	0		No
BusN45	BayshoreandSears_S1	1	1081	1	0		No
BusN46	BayshoreandSears_S1	1	1115	1	0		No
BusN47	BayshoreandSears_S1	1	1150	1	0		No

Figure 42 ProModel R14 Simulation Model-Bus Entity Arrival

4.2 Transit Plus Data Pre-processing using ArcGIS

Earlier in Chapter 1, we described potential PWDs who currently use the ADA paratransit system but are candidate to be added into the fixed bus route system as PWDs located under 0.5 mile of R14. In order to acquire the potential passengers' information as accurately as possible, we use Geography Information System (GIS) software - ArcGIS Desktop version 10.2.2 and ArcGIS online to assist in distinguishing the potential PWDs for fixed bus route services. The flow chart in Figure 43 shows the procedure followed using the GIS software. The spatial distribution map of paratransit riders near R14 are shown in Figure 44.

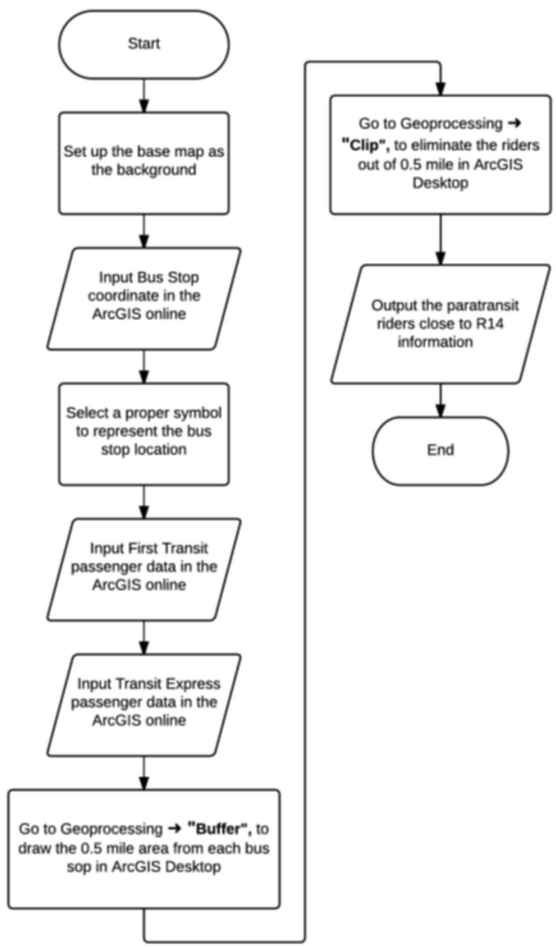


Figure 43 Procedure of using ArcGIS Software to Separate the Paratransit Riders nearby R14

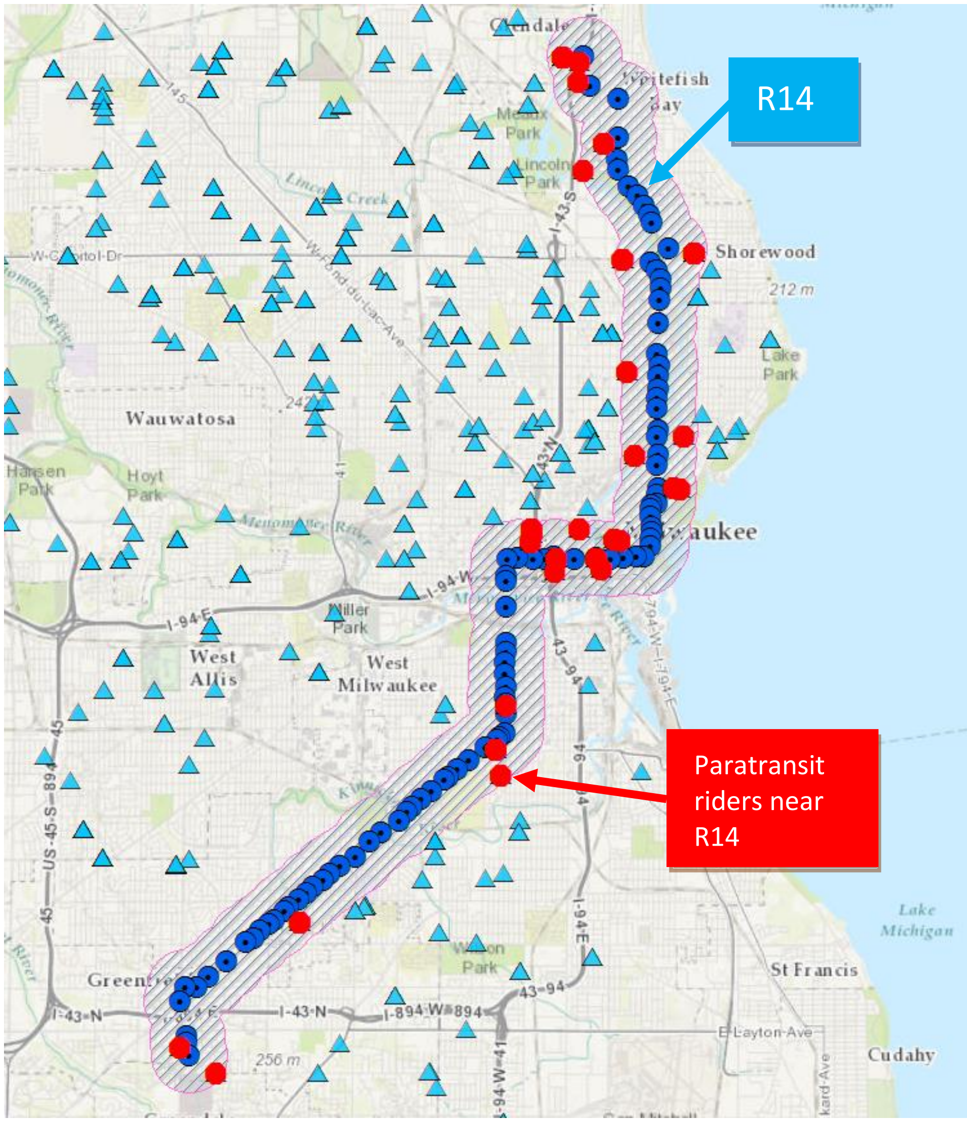


Figure 44 Map of Paratransit Riders nearby R14

4.3 Simulation Model (II) – Additional Potential Riders from Transit Plus System

As each PWDs' request for paratransit service has the date, address, and destination information. Using the date information, we are able to extract seasonal ridership information as well. We make an assumption that all potential riders are able to use the fixed bus route system, hence increase the fixed route bus ridership in the initial simulation by the potential PWDs. Figure 45 shows the average additional rider close to the R14 per seasonal. Table 15 is an illustration of fixed route service and potential additional riders' data consolidation. The simulation result and outcome will be discussed in the Chapter 5.

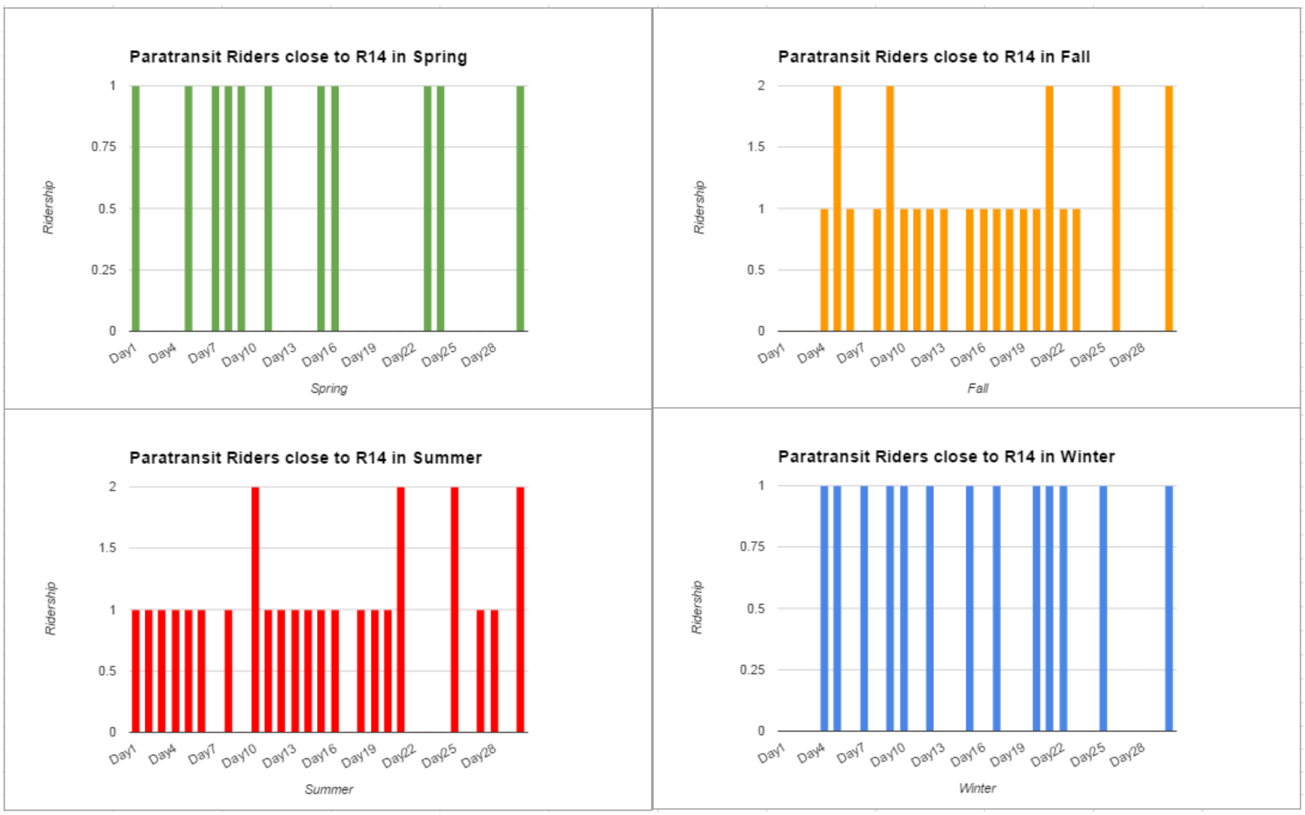


Figure 45 Paratransit Ridership in Different Season

Table 15 Additional ADA paratransit Ridership add to Model II

Model I(Fixed route Riders***)***		Plus Paratransit Riders	***Model II*** (Fixed bus route ADA Riders + Paratransit Riders***)***	
Spring			Spring	
Day1	4	4+1	Day1	5
Day2	7	7+0	Day2	7
Day3	4	4+0	Day3	4
…	…	…	…	…
Day30	9	9+1	Day30	10

Chapter 5 Simulation Model Results and Discussion

The discussion in this chapter will be sequential following the study objectives presented in Chapter 1.

5.1 Objective 1 Results and Analysis

Objective 1 focused on gathering and pre-analyzing data to determine the current usage of fixed bus route and ADA paratransit services. This will serve as a baseline for the current and future studies. In Chapter 3, we presented the ridership data first for the Fixed Bus Route Service that was acquired from the MCTS Paratransit Office. As mentioned earlier, this study focused on ridership of PWDs to the most visited destinations, i.e. the Potawatomi Hotels and Casino as well as the V.A. Medical Center. Therefore, year-long data for routes 14, 23 and Blue were presented for the south and north bound directions. Since some months' data was missing, the data was consolidated into seasons (winter = December to February, spring = March to May, summer = June to August and fall = September to November). Data for each season was reported as the average ridership of the months within the season for 30 days. We clarify here that the days, 1 to 30, were not checked to find out whether they were weekday or not. Thus, the weekday/weekend dynamic details and differences were lost. An Analysis of Variance (ANOVA) was carried out to determine if the seasonality had a major influence on ridership for each route.

5.1.1 R14 PWD Ridership Analysis

Though the adjusted R-squared was 52.41%, both the day of the seasons as well as the seasons were found to be significant at 95% significance level. Specifically the p-values were found to be 0.018 and < 0.00005 p-values respectively. Since we are not necessarily interested in obtaining an exact regression model, the interactive effect of both variables was not tested. Moreover, the Post-Hoc Tukey test was carried out to determine the seasonal difference and all seasons were indeed significantly different in ridership. Figure 46 is the resultant plot of the average ridership per season.

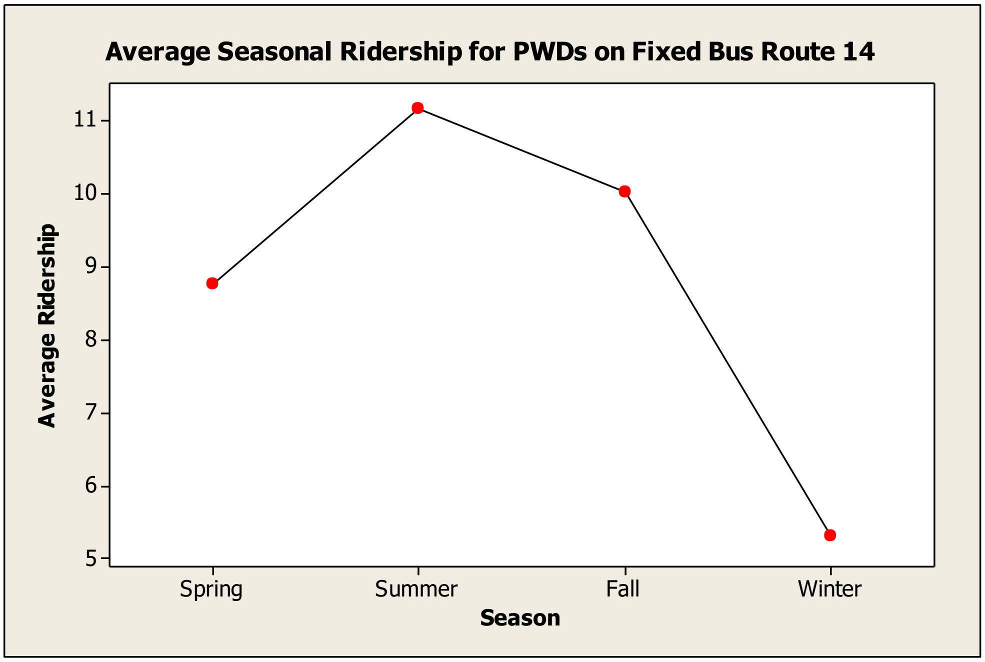


Figure 46 Average Seasonal Ridership for PWDs on Fixed Bus Route 14

As expected, winter had the lowest ridership while summer months had the highest (double) ridership.

5.1.2 R23 PWD Ridership Analysis

After carrying out the ANOVA for R23 ridership, the adjusted R-squared was 64.53%, a lot better than the previous route results. Both days of the seasons as well as the seasons were found to be significant at 95% significance level. Specifically the p-values were found to be 0.036 and < 0.00005 p-values respectively. Similarly, we are not certainly interested in obtaining an exact regression model; the interactive effect of both variables was not tested. The Post-Hoc Tukey test also showed the seasonal difference and all seasons were indeed significantly different in ridership. Figure 47 is the resultant plot of the average ridership per season.

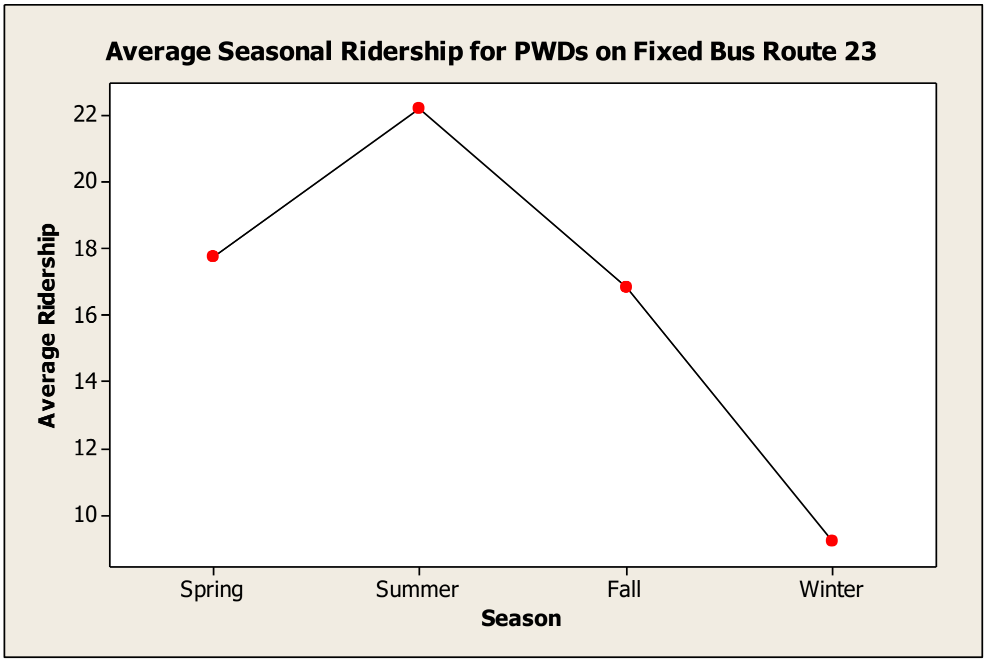


Figure 47 Average Seasonal Ridership for PWDs on Fixed Bus Route 23

5.1.3 RBlue PWD Ridership Analysis

The ANOVA for the effect of seasonality and day of season on RBlue ridership resulted in an adjusted R-squared of 63.41%. The seasons were found to be significant at 95% significance level, but the day of the week was not significant. Just for the record, the p-values were < 0.00005 and 0.361 respectively. Figure 48 is the resultant plot of the average ridership per season. From all the above ridership analysis, it is evident that fixed route riders to the V.A. Medical Hospital is more than double the ridership to the Casino across all seasons.

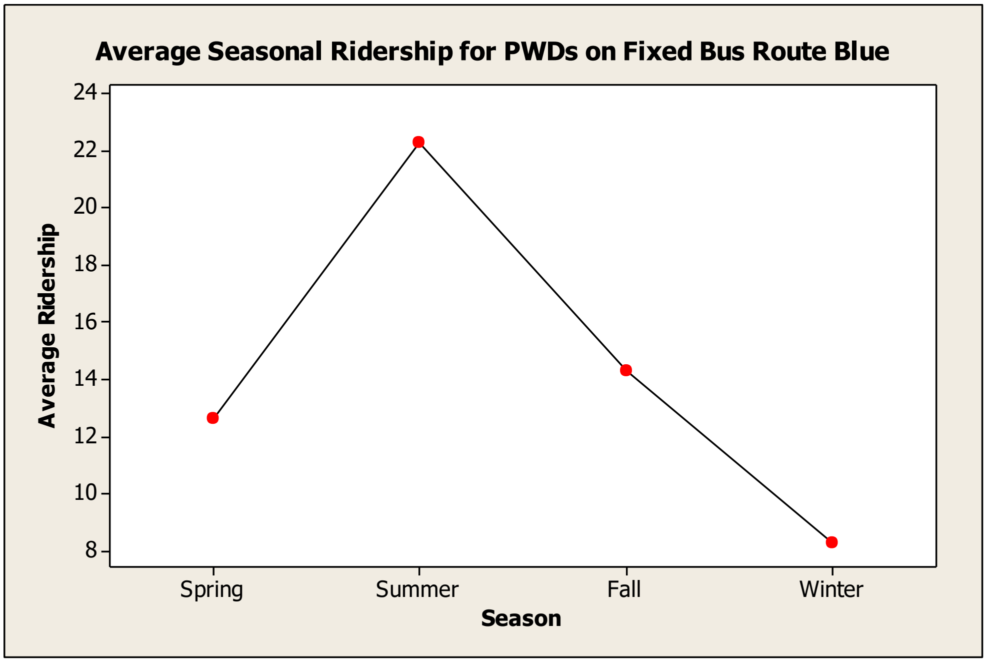


Figure 48 Average Seasonal Ridership for PWDs on Fixed Bus Route Blue

5.1.4 Transit Plus Ridership Analysis-Casino Destination

Unlike the fixed bus route services that presented significant seasonality, the ADA paratransit data from Transit Plus had neither seasonality nor day-to-day significance. The ANOVA results indicated p-values of 0.544 and 0.844 respectively. However, the adjusted R-squared value was quite low, at 25%, thus we conclude that variations in ridership may be affected by other factors or may all together be random. Figure 49 shows that the average transit plus ridership for each season in the year is at about 8.

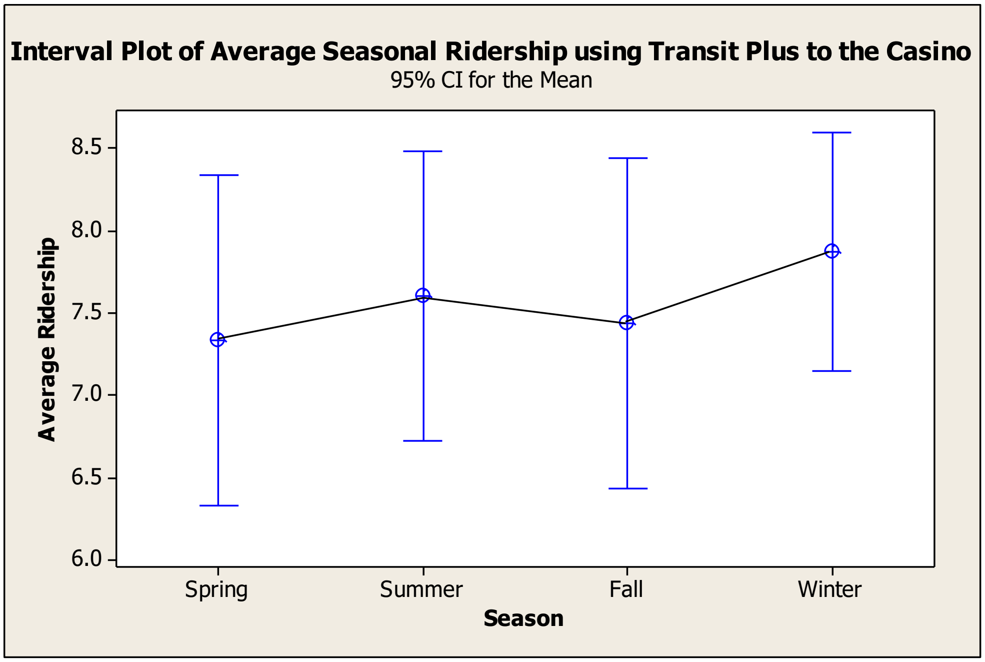


Figure 49 Average Seasonal Ridership for PWDs using Transit Plus to the Casino

In chapter 3, a density map of riders using Transit Plus to the Casino was presented in Figure 29. It seems to be evident that most PWD riders to the Casino leave away from R14. This means that though it may be useful for the Casino to fix the bus stop, it may also be useful for the MCTS to revisit their bus network of routes if this sent of potential clientele is to be served.

5.1.5 Transit Plus Ridership Analysis -V.A. Destination

The V.A. destination ridership likewise presented neither seasonality nor day-to-day significance. The ANOVA results indicated p-values of 0.791 and 0.335 respectively. As well as the adjusted R-squared value was low, at 27.81%, thus we draw the same conclusion that other factors affect the variations in ridership or may all together be random. Figure 50 shows that the average transit plus ridership for each season in the year is at about 6.

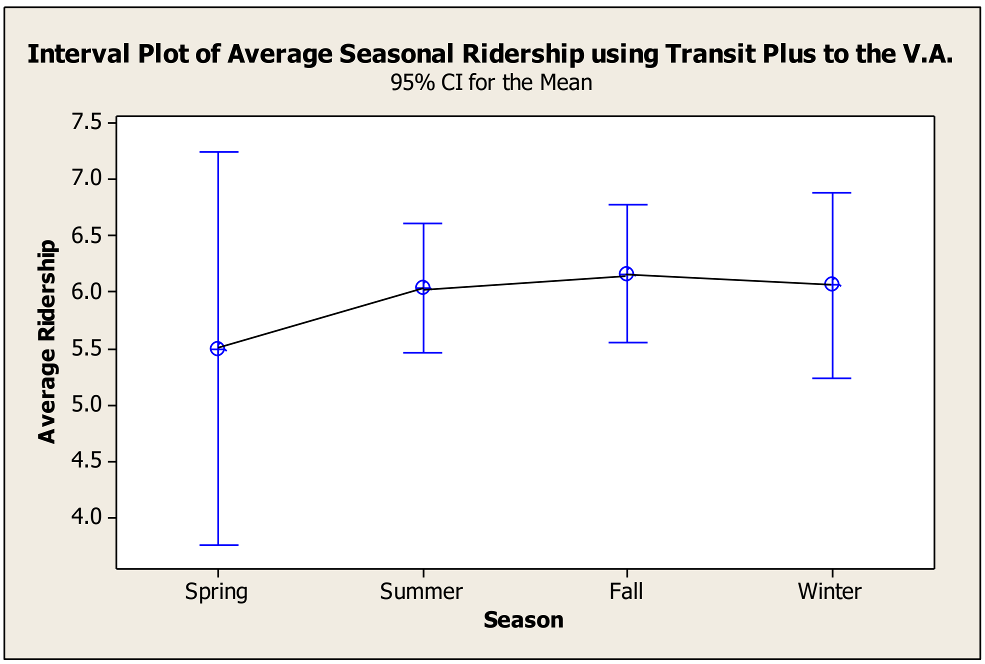


Figure 50 Average Seasonal Ridership for PWDs using Transit Plus to the V.A.

In chapter 3, a density map of riders using Transit Plus to the V.A hospital was presented in Figure 26. Two bus route (R23 and RBlue) enhance the region to cover more PWD riders to the V.A hospital. These two route have overlap in the south side, this means that the bus service will provide higher frequency of arriving. In other word it will increase the motivation of taking the bus line.

5.2 Objectives 2 & 3 Discussion

Objective 2 focused on simulating the current fixed route service for PWDs to the Casino destination in order determine the current performance metrics including bus utilization, client waiting time, client time in the system, and total system cost (both client and MCTS). Objective 3 on the other hand focused on adding potential PWDs who initially used the ADA paratransit system into the fixed route service simulation to determine the performance metrics such as bus utilization, client waiting time, client time in the system, and total system cost (for both client and the MCTS agency).

From the implementation of objective 2 the following results as shown in Table 16 were obtained from the simulation when the current ridership of the fixed bus route system was considered. Two main discussion points from these findings are:

5.2.1 Waiting Time

Table 16 indicates that the average waiting time from Model I ranges from 9.79 to11.65 minutes with 95 % confidence intervals between 8.49 and 13.09 minutes. As for passengers with wheelchairs, the average waiting time ranged from 8.24 to 11.52 minutes, and with 95 % confidence intervals between 7.81 and 13.44 minutes. After additional potential PWD riders were into the simulation (Model II), there were no marked differences in average riders per season as shown in Table 17. Likewise, the change in passenger waiting time as well as the wheel chair waiting time increased by about 1to 2 minutes. Though we did not compare the average waiting time in our simulation with the estimated waiting time of the general public, in Figures 51 and 52, we can note that the MCTS R14 bus schedule indicates that 90% of the waiting time at each stop is less than 17 minutes. Hence the waiting time might defiantly cause a challenge for PWDs especially in the harsh winter days. Looking at the wheel chair users, their waiting time is considerably equal to the waiting time of non-wheel chair users. However, subjecting a wheel chair user to close to 14 minutes (at 95% confidence intervals) of waiting also adds more difficulty for them to use the fixed bus routes. In addition to this substantially long waiting time, the unfriendly bus stop environment at the Casino as well as the impassable pavements during winter days pose increasing challenges to PWDs using wheelchairs or scooters.

Table 16 Fixed Bus Route Simulation Result

Fixed bus route (Model I)					
	Average ridership per day	Passenger waiting Time (min) (without wheel chair)	95% Conf. Interv. for Passanger waiting time (without wheel chair)	Passenger with wheelchr waiting time(min)	95% Conf. Interv. for passanger with wheel chair waiting time
Spring	7	9.79	[8.49, 11.09]	9.62	[7.81, 11.43]
Summer	8	11.65	[10.22, 13.09]	11.9	[10.58, 13.22]
Fall	7	11.05	[9.57, 12.54]	11.52	[9.60, 13.44]
Winter	5	10.83	[8.96, 12.69]	8.24	[6.25, 10.23]

Table 17 Fixed Bus Route Plus Potential PWDs Riders

Fixed bus route plus Potential PWDs Riders (Model II)					
	Average ridership per day	Passenger waiting Time (min) (without wheel chair)	95% Conf. Interv. for Passanger waiting time (without wheel chair)	Passenger with wheelchr waiting time(min)	95% Conf. Interv. for passanger with wheel chair waiting time
Spring	7	10.56	[9.13, 11.992]	10.39	[8.57, 12.21]
Summer	9	11.76	[9.58, 13.94]	11.32	[9.44, 13.20]
Fall	8	12.01	[9.88, 14.15]	10.73	[8.85, 12.62]
Winter	5	10.48	[9.74, 13.28]	11.51	[7.93, 13.04]

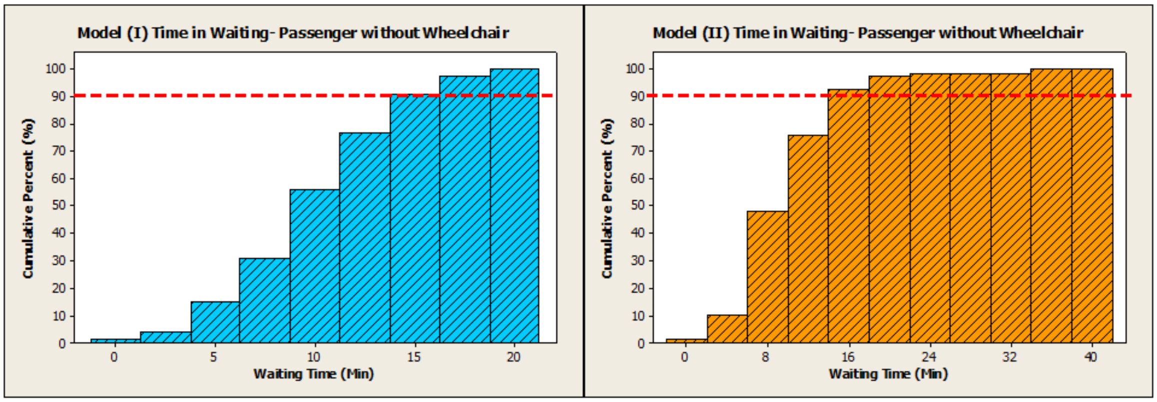


Figure 51 Waiting Time Cumulative Distribution Model I & II (No Wheelchair)

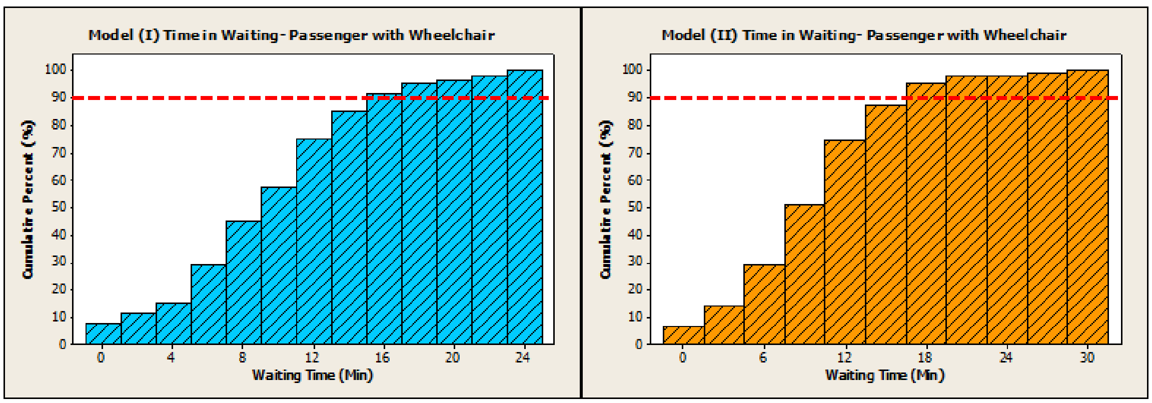


Figure 52 Waiting Time Cumulative Distribution Model I & II (With Wheelchair)

5.2.2 Time in the System

The average time in the system for non-wheel chair and wheel chair passengers ranged between 32.8 and 35.53 minutes, with the 95% confidence interval of 29.87 to 38.34 minutes (Table 18). The main point of discussion here is that in Milwaukee, the ADA transit plus system requires that a passenger's time in the system (from pick-up to drop-off) should not exceed 30 minutes if no congestion or worse traffic happened. The results from Table 18 shows an upper 95% confidence intervals limit of 38.34 minutes. Moreover, Figures 53 and 54 show that 90% of the time in system is under 42.5 minutes. Hence we envision that such a difference will be a great determining factor for PWDs especially those with ambulatory disabilities to decide to use the transit plus system instead of the fixed bus route system.

Table 18 Model I & Model II Time in system

	Fixed bus route (Model I)		Fixed bus route plus Potential PWDs Riders (Model II)	
	Average time in system(min)	95% Conf. Interv. for time in system	Average time in system(min)	95% Conf. Interv. for time in system
Spring	33.6	[31.08, 36.08]	34.78	[32.37, 37.19]
Summer	35.89	[33.69, 38.09]	34.84	[32.59, 37.11]
Fall	35.84	[33.53, 38.16	34.46	[32.27, 36.66]
Winter	32.8	[29.87, 35.68]	35.53	[32.84, 38.34]

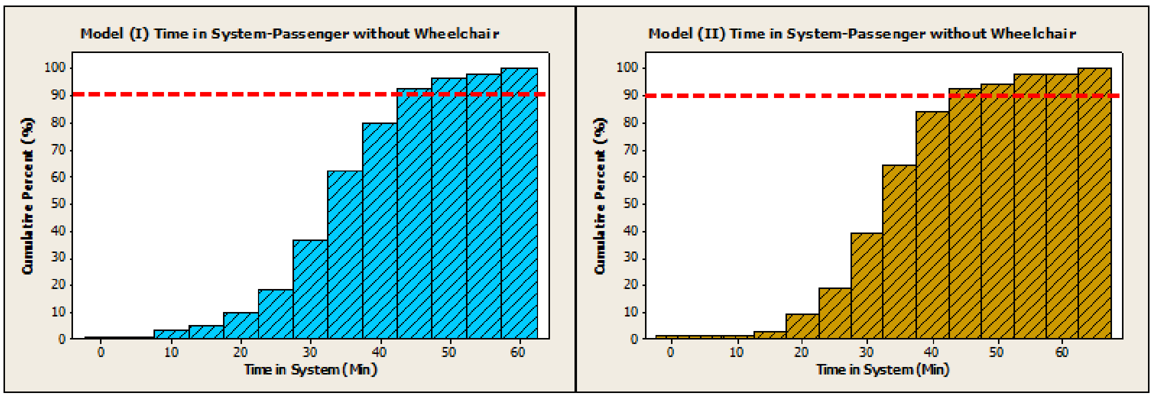


Figure 53 Time in System Cumulative Distribution Model I & II (No Wheelchair)

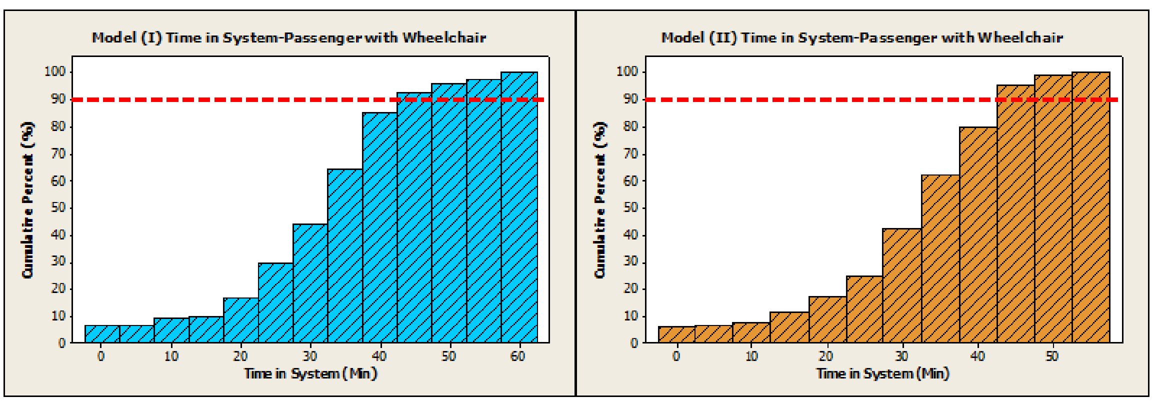


Figure 54 Time in System Cumulative Distribution Model I & II (With Wheelchair)

5.2.3 Bus Utilization

The final discussion will focus on the bus utilization, which was calculated as:

$$Bus\ utilization = \frac{\text{\% of bus runs with at least one PWD}}{\text{Total number of bus runs in a day}}$$

In our simulation the total number of runs in a day was about 90. Hence the bus utilization ranges from 4.5% to 8.8 % (Table 19). This really means that there is adequate capacity for more PWDs to ride on the buses. However, the limitation in this conclusion is that the rest of the general public passengers were not incorporated into the simulation which would greatly affect the capacity, bus congestion as well as congestion in the bus stop, all of which do play a major role in PWDs decision to use the fixed bus route system.

Table 19 Model I & Model II Bus utilization

	Fixed bus route (Model I)	Fixed bus route plus Potential PWDs Riders (Model II)
	Bus utilization (bus used/ total bus run)	Bus Utilization (bus used/ Total bus run)
Spring	6.60%	6.90%
Summer	7.90%	8.80%
Fall	7.10%	7.70%
Winter	4.50%	4.70%

5.3 MCTS Operation Expense

Table 3 presented in chapter 2 gives the total ADA transit expenses that MCTS incurred in 2013 (including the ADA fixed route bus boarding as well as the Transit Plus Service usage. We used this data to calculate the cost per passenger as $28.86 and $3.17 for the ADA paratransit service and the fixed bus route service respectively. Since the simulation in the study only involves R14, Table 18 is a summary of the system cost for R14. The total (annual) riders to the Casino via fixed route services and Transit Plus Services was 730 and 2,664 (before extracting potential bus route riders) respectively. These values when multiplied with the cost estimates lead to total costs of $76,883.04 for Transit Plus and $2,314.10 for fixed bus route. Thus the transit plus costs (to the Casino) outweighs the fixed route bus to the Casino by close to thirty times. This means that though the overall (for the MCTS network) cost ratio was 15:1 (transit plus to fixed bus route) considering travel to the Casino alone, this ratio doubles to 33:1.

Table 20 also shows the cost analysis after about 172 potential PWD users were switched to use the fixed bus route system. We noticed that the annual cost of transit plus reduced by about $5,000 (to $71,919.12) while the annual cost of fixed route increased by about $500 (to $2,859.34). The ratio of transit plus cost to the fixed bus route cost also reduced to 25:1. This is a remarkable change in system cost resulting in an annual 5% decrease in total costs.

Table 20 Total Ridership and Expense Comparison

	Transit Plus	Fixed route service (60% ridership)	MCTS Total Expanse	
Total Ridership	2,664	730		
Expense	2664 * $28.86 = $76,883.04	730 * $3.17 = $2,314.10	$79,197.14	
Additional Potential PWDs Riders Added	2,664 - 172	730 + 172		
Total Ridership	2,492	902		Decrease percentage
Expense	2,492*28.86 = $71,919.12	902*3.17 = $2859.34	74,778.46	5%

5.4 Expenses to the Individual Riders

According to the cost of ridership in Milwaukee County, the ADA paratransit through transit plus program cost each user $3.50 for travel within Milwaukee County. Ideally, the cost per ADA paratransit rider is $25, so MCTS covers the reminder ($21.50) for each rider. If PWDs would reconsider the mode of travel and switch to the fixed route bus services, they would pay $1.15. Furthermore, if ADA passenger has the eligibility criteria that would qualify them to get the “Go free” bus pass in Milwaukee county, then they would always ride the fixed route buses for free. These eligibility criteria are similar to the qualification specified by the Americans with Disability Act for identity PWDs.

5.5 R14 Geographical Cover Region

A map of R14's coverage was presented in Chapter 4. In addition, we superimposed the ADA paratransit ridership data onto R14's bus route map. We noticed that the densest regions i.e. locations where most ADA ride demands to the Casino originated from, were about 2 miles away from R14 bus route. We also realized that out of n=664 riders to the Casino using First transit (serving the southern regions of Milwaukee) about 5% of these riders live within 0.5 miles of R14 bus route. Likewise, out of n = 1996 ADA riders who use Transit Express (north serving), only 11% of the riders reside within 0.5 miles of R14 bus route. Ideally, all the 2,660 PWD riders are potential customer of the MCTS fixed bus route paratransit service. However, realistically, we know that not all of them are willing to use the bus. However, if MCTS would revisit the bus network and incorporate these dense regions into the route that serves the casino; more ADA riders would opt to use the bus.

5.6 Casino Bus Stop Accessibility

In [27], it mentioned improving bus stop accessibility not only benefits riders, but also enhances the usability of all riders. In fact, the ADA which was enacted in 1990 requires every region in United Stated to follow the bus stops design specifications. A detailed discussion regarding accessibility of the V.A. Medical Center and the Potawatomi Casino has been discussed widely in Section 3.2.1 of this Thesis. We realized that the V.A. bus stop is accessible by both north and south bound R23 and RBlue bus routes. Due to time constraints the researcher was not able to complete the simulation for these two routes. Further analysis of R23 and RBlue has been left for future studies. The Casino bus stop on the other hand, does not meet most of the bus stop accessibility criteria, particularly distance from the stop to the Casino entrance, lack of bus stop shelter, absence of an accessibility ramp and most important the need for north bound clients to cross the busy highway to and from the Casino.

Chapter 6 Conclusion, Limitations and Future Study

6.1 Conclusion

The study presented in this Thesis resulted from collaborative efforts between UWM's Industrial and Manufacturing Engineering team, UWM's Director of the Rehabilitation Research Design & Disability (R2D2) Center, Milwaukee County Office of Persons with Disabilities team and the MCTS-Paratransit Department Team. Since March 2015, the MCTS has been rolling out the Go Free program that provides eligible PWDs with free ride passes on the fixed bus route service. MCTS hence wanted to explore effect that increased ADA bus ridership would have on the system performance such as bus utilization by PWDs, PWD average waiting time as well as the average time in the system. Since the MCTS network is large, the team determined to pilot the study on the most used routes by PWDs in Milwaukee County that serve the two most visited destinations, namely, the **Potawatomi Hotel & Casino** (Casino) and **Milwaukee Veterans Affairs Medical Center** (V.A.).

The objectives of this study were divided into three. First, we sought to understand the current status of ridership for the R14, R23 and RBlue fixed routes to serve as a baseline for the current and future research. The number of PWDs in Milwaukee County is estimated to be 13% of the population. Year-long real ridership data was obtained from MCTS Paratransit Office. This data included both north and southbound directions of the three routes. The results indicate that paratransit ridership much outweigh ADA ridership on the fixed route bus service by a ratio of 3 to 1. This ratio is remarkably lower than the ratio that has been reported for Chicago which is at 1:8 [4], albeit the inherent differences between the two cities, including population, demographics, economic, transportation network as well as the transportation pricing. This difference presents a potential increase in fixed route riders in Milwaukee, if hindrances to bus ridership by PWDs are addressed and remedied. These include driver training, public awareness to address societal stigmas regarding disabilities, bus frequency and availability issues as well as bus stop design. Analysis of variance results showed that seasons significantly affected ridership of the fixed bus route system, with a maximum daily ridership of about 11 PWDs in the summer and 5 in the winter use bus R14 to the Casino, about 22 PWDs in the summer and 10 in the winter use bus R23 to V.A. as well as about 22 in the summer and 8 in the winter use bus RBlue to V.A. Transit plus ridership on the other hand did not vary significantly by season, and the average daily ridership was about 8 to the Casino and about 6 to V.A.

The second objective involved simulating the current fixed route service for PWDs to the Casino destination in order determine the current performance metrics (simulation model I). This objective is closely related to the third objective which focused on adding potential PWDs who initially used the ADA paratransit system into the fixed route service simulation (simulation model II), to determine the performance metrics in comparison to simulation model I. We used a geo-spatial simulation approach that interfaced Batch Geo, ArcGIS and ProModel. The results indicated that the performance criteria did not change remarkably from Model I to II. This is because there were a few potential transit plus riders (those live 0.5 mile within the bus route) who could switch to the fixed bus services. In Model I, the results indicated that the annual ridership was on average 7 PWDs per day. The 95% confidence interval of passenger waiting time was [10.22, 13.09] minutes which evidently was in the summer. On the other hand, the 95% confidence interval of the average waiting time in winter, was [8.96, 12.96] minutes. Since the buses can only have room for at most two wheel chair or scooter users; we intended to understand if this constraint affects the average waiting time of PWDs on wheelchairs. The 95% confidence interval of the average waiting time for PWDs using wheel chairs was [10.58, 13.22] in summer.

In the Model II, the 95% confidence interval of the average waiting time for non-wheelchair users was [9.88, 14.15] minutes, and the average waiting time for wheelchair users was [9.44, 13.20] minutes. Thus, the waiting time of PWDs on wheelchairs did not change remarkably compared to the rest of PWDs. This means that R14 still had room to accommodate more PDWs on such ambulatory assistive devices.

The other performance metric in this study was the average time in the system, representing the average time it would take a PWDs from the origin to their destination. The 95% confidence interval for average time in the system for all passengers (with or without mobility devices) was about 29.87 to 38.34 minutes. We realized that following MCTS transit plus requirement, a passenger's time in the system (from pick-up to drop-off) should not exceed 30 minutes in regular traffic. Thus if the total time in the system using a bus exceeds 30 minutes, this metric—time on the system, would easily be the make or break criteria in the decision to either use the ADA paratransit service or the fixed route bus service, especially for PWDs with ambulatory disabilities.

Further the bus usage was analyzed. Bus usage is defined as a percentage ratio of the number of bus runs in the simulation carrying a PWD to the total bus runs. This value was on average (across seasons) 6.5%. This means that there is still potential in encouraging more PWDs to use the bus system. However, factors such as bus network coverage and bus stops accessibility among other ridership challenges will need to be addressed.

6.2 Limitations

A few assumptions were made in this study, either for the purpose of computation, especially when information was missing from the data source. These limitations are summarized as follows:

1. Since the real fixed bus route ADA boarding tallies are made by drivers, the actual boarding time as well as boarding location is never recorded. Thus in this study, the percentage of riders stratified by time periods of the day were estimated using ADA paratransit data as discussed in Chapter 3. These percentages were 30% from 6:00 to

7:30, 20% from 7:31 to 13:00, 30% from 13:01 to 16:30 and 20% from 16:31 to 21:00. The actual simulation arrival times as well as the bus stop at which each ADA boarded from were generated from a uniform distribution.

2. The percentage of ADA passengers that go to the Casino using R14 was arbitrary chose to be 60%. The rationale for choice of 60 is because the data from MCTS does not include the ridership drop off destination.
3. We also recognize that the ADA boarding tallies kept by the drivers is subjective and may easily be an underestimate of actual ridership. This is because drivers can only count ADA riders whose disability can be perceived by the eyes. Since early 2015, the MCTS rolled out the Go Pass free ridership to all eligible PWDs, so going forward, ridership data will automatically be logged into the individual PWDs account, hence provide precise and detailed account of ADA ridership.

6.3 Future Study

This study has several immediate and extensive areas of future research. First, a simulation could be done that combines both PWDs and the general public to determined actual usage, waiting time and time in the system when the problem becomes capacitated by seat availability. Second, similar simulation models should be implemented for R23 and RBlue and third, actual data of ridership to the Casino and V.A. using the fixed route service should be obtained. Currently, MCTS keeps a tally of total riders per route for each direction (south or north bound), without keeping tabs of their origin and destination.

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